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SUPPLEMENT TO THE

MYSORE GAZETTE.

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REPORT ON COFFEE LEAF DISEASE, '(*HEMILEIA VASTATRIX.*)'

1. In compliance with the orders of the Chief Commissioner of Mysore and Coorg, I have the honor to submit the following report of "*Hemileia Vastatrix*" from an agricultural standpoint.

2. I reached Coorg on February 1st 1879, and returned to Bangalore on April 29th, having traversed the coffee districts of Coorg and Mysore throughout their entire length, and inspected a large number of estates on which coffee cultivation is carried on under widely varying conditions.

3. On my arrival at Mercara I placed myself in communication with the Honorary Secretary of the Coorg Planters' Association, who aided me materially in collecting information, and in suggesting the routes by which my investigations of typical estates could be most advantageously undertaken. Unfortunately ill-health prevented my seeing some few estates remote from Mercara, but though this is to be regretted as somewhat restricting my range of obvservation, I found no indications on the most outlying estates visited that a further progress in these particular directions would yield any new fact of importance.

4. With the object of interesting as many planters as possible in the investigation, and acquiring from them information which their daily observation, or opportunities for observation on the coffee tree at all times and seasons should supply, I requested the Honorary Secretary of the Coorg Planters' Association, and subsequently the Honorary Secretary of the Mysore Planters' Association, that the subjoined list of questions might be printed and distributed and the replies forwarded to me:—

It is requested that concise answers may be given to any or all of the following questions.

State the name of the estate to which your answers refer, your length of experience of coffee planting, and of the particular estate to which your answers refer.

I. What is the age of the estate?
II. ,, ,, average rain-fall?
III. ,, ,, maximum and minimum rain-fall?
IV. ,, ,, effect of an unusually heavy or light monsoon?
V. ,, ,, nature of shade, dense or otherwise?
VI. ,, age of the plants most commonly attacked?
VII. Is the disease increasing or decreasing in intensity?
VIII. At what times of the year does the disease appear and disappear?
IX. What is the effect on the disease of heavy rain showers, cloudy weather, fogs?
X. Is the disease more virulent on trees growing on any particular aspect?

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XI. When did you first notice the disease ?
XII. Was the original jungle on your estate burnt or rotted ?
XIII. Is the disease more severe after one or more heavy crops ?
XIV. Has heavy pruning any influence?
XV. Have you had any experience in surface draining ?
XVI. " " sub-soil " ?
XVII. What manures are commonly used and what is their effect ?
XVIII. Are fungus growths plentiful on other trees when this disease is heaviest on coffee trees ?
XIX. Do you consider the disease spreads ?
XX. Can you give analyses of your rock, soil or sub-soil ?

5. I regret to have to remark with regard to the replies of the Coorg planters that their number was exceedingly limited, and generally those received contained but meagre information. I also found facts which would have been of much service in a scientific examination occasionally withheld, from an objection to confess the parsimonious and ignorant methods of cultivation on which some estates had been conducted. The evidence that bad cultivation predisposes the coffee plant to disease, which I believe might be recounted without end, is thus less strong than it would otherwise appear, had it been fully recognized that my investigations were not to expose the mismanagement of particular estates and damage their commercial value, but to arrive at facts whose elucidation would be of benefit to the entire planting community, and not a cause of injury to a single individual. To conduct an examination of such a subtle disease as that now under consideration with any degree of success, requires that all possible information should be at command, but it will be some time, at the rate we are now progressing, before the requisite amount of evidence is collected to complete the history and cure of this pest. Unless planters make up their minds either to make experiments with a definite end in view and record both the positive and negative results of these questions to nature, and also appoint a properly qualified man to direct the enquiry and tabulate the replies, I see small prospect of a widely spread and thorough conquest over this and other natural difficulties attending coffee cultivation. Although each planter may stumble on facts which are useful to himself and those of his neighbours to whom he may communicate them, in many cases a far larger benefit would accrue if the facts were made public and the explanation of the causes that led to a certain effect were understood. I was much struck on several occasions with the thoughtless readiness with which a lead was followed and considerable quantities of manure purchased by one planter simply because another said he had obtained or was going to purchase a supply of the article. Further enquiry generally shewed the original purchaser merely thought he had derived benefit from the application of the manure ; but absolute proof by comparative experiments of a reliable nature was wanting. The crude test, occasionally applied, of comparing the yield of one manured field against another, is fallacious, especially on such lands as those devoted to coffee cultivation, because it seldom happens that the same conditions are met with over any considerable area. Either depth and quality of soil, change of slope or aspect, age of the plants, previous cultivation or variety of shade render absolute similarity impossible. Yet to learn what the increase of crop is due to a manure, a different system of cultivation, or whatever may be the cause it is wished to compare and estimate, is a very simple matter. Half a dozen, or better a dozen rows of bushes, taken from the top to the bottom of a slope should be left unmanured if the effect of manure is to be ascertained. When the crop is picked that yielded by the centre rows should be kept separate and weighed both in berry and parchment, as the proportion of these may vary. The two outside rows must not be added as they will be unreliable from the plants in them receiving a partial benefit from the manure on one side. A similar area of land to that covered by the unmanured rows should be marked off on the manured portion and the crop picked and kept separate until weighed. The difference in yield may rightly be estimated to be that due to the manure, and a simple comparison of the value of the increase of crop and the price of the manure applied will shew in what degree the application is remunerative. I am well aware of the difficulty of getting accurate results if the coolies are not closely watched, but as the plots need not be large—say not more than one-tenth acre areas—personal supervision might be given, as the time taken in picking such limited areas would not be great, while the benefit of knowing the exact value of the manure would, I believe, fully compensate the planter for the extra trouble taken. To those who desire but moderate accuracy and cannot afford time for a lengthy supervision, the comparison of a single plot unmanured and single plot manured may suffice, but to reduce the chances of inaccuracy from natural and accidental causes, it is desirable to try all experiments of this nature on duplicate plots and take the mean of results. Such a system of experiments can be extended *ad libitum* to allow of the comparison of any manure, applied simply alone or combined, of cultivation, of heavy and light pruning, or any operation that

it may be considered worthy such comparative testing. As the effect of many manures is not fully developed the first year and it may extend over several, no experiment can be considered complete that records the result on one crop only. To mark the plots so that their position does not become lost becomes therefore a necessity, and to record results a note book with pages ruled on a plan to correspond with the plots in the field should be carefully posted up. In recording the results of an experiment it must be remembered that it is essential to mark negative as well as positive results and the influence on leaves and wood as well as on the crop. The knowledge that a manure had no effect the first year becomes useful, if it be found to act the second, as then a too hasty conclusion that it is useless is avoided. Again, a manure that forces a crop at the cost of weakening the plant to such an extent that it does not recover for one or two seasons, renders a complete and continuous record desirable. I consider managers of estates omit a very material part of their duty if they do not record fully the history of each field continuously. It is often asserted that a coffee tree is grateful for any manure, but it is true that it may be supplied with a food containing a variety of component parts, only some of which it will absorb, while the remainder are unnecessary. Agricultural chemistry has shewn on what a plant feeds, and an analysis of the soil tells us what nature unaided has given us as capital. We know within certain limits what we take away in a crop of coffee, so we should know what to return as manure and how to return it, and whether we can draw with certainty on the soil for a further supply of this or that constituent without fear of a temporary or permanent exhaustion ; or if an element so deficient or unavailable, that an addition by purchase becomes necessary. Then comes the financial question in what form can the desired food be most cheaply obtained and to this an answer can be found best by experiment. The line of thought should not be—

6. It may be urged that considerable gains have been obtained by growing coffee without a recourse to science, and that the natural richness of the land on which the bush is generally grown ensures such a profit that attention to details is unnecessary. I know one swallow does not make a summer, but I would draw attention to the difference in the analyses of the soil of a Mysore estate given elsewhere in full, which bears out what I am discussing.

	No. II. Virgin soil.	No. III. After 10 years under coffee.
Lime	·90	·40
Magnesia	·38	·20
Potash	·45	·35
Phosphoric pentoxide	·31	·20

This shews in an unmistakable manner the gradual exhaustion of the most scarce constituents in a soil of unusual richness. Had similar analyses been made of a poorer soil, the figures would shew a nearer approach to exhaustion, while recourse would have had to have been made at an early period to a system of manuring which has only recently been commenced on this estate as a matter of necessity.

7. I believe large estates cultivated in the way I have found many to be are not nearly so remunerative as smaller ones where a higher system of cultivation is adopted, and I consider planters in Mysore and Coorg would do well to follow the example set them by many planters in Ceylon and use the poorer portions of their estates for the cultivation of such fodder as Guinea grass that serves to feed cattle, and thus give a means to keep up the fertility of the better portions which pay well to cultivate highly under coffee. The increasing difficulty in obtaining labor must eventually tend to check estate expansion, and I feel I must here bring forward the following remarks of a Coorg planter on this important matter written in answer to my questions, although not strictly replying to any of them.

" I will add that there is one cure for leaf disease, and that is a good labor contract act by which we may be sure that when we engage 300 coolies to work the place, we may rely on 250 at least, not as at present when we engage say 500 coolies and think ourselves lucky if we get 100. And if you would kindly impress on the Chief Commissioner the impossibility of working our estates without coolies and point out that although a planter may understand thoroughly the means of reducing leaf disease, borer, &c., to a minimum, he is utterly powerless without labor, and that a number of planters are afraid that this year this will practically be our case ; you will be doing a great service to the Planting Community of Coorg, as we all feel that for Government to deny a labor contract

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act and at the same time send a scientific man to point out the means of mitigating coffee diseases, is rather like holding a plank just out of reach of a drowning man as we would be only too glad to take the necessary steps, could we depend on our labor and not, as at present, when one is only too thankful to get through the year with the roughest style of cultivation owing to want of labor, having engaged 500 coolies to work the place only 100 of whom are procurable."

Again, a Mysore planter concludes his paper as follows :—

"Finally I beg to remark that one of the greatest difficulties most planters in Mysore have to contend with is the want of a plentiful and regular supply of labor caused in part by the action of Government or rather I should say by its want of action, for whilst it is willing to allow the surplus working population of the country to be carried away to distant Colonies of England and even to foreign countries and to our near competitor Ceylon, it will make no laws for the proper regulation of the relation between planters and their laborers in India, and as regards Mysore the case is even worse. As in Ceylon the cry as a cure for leaf disease is Railway extension, so should it be in India a labor law.

In proof of the urgency of the case I may mention that I only met a single planter in Mysore who had sufficient labor. It would be beyond my sphere to discuss this subject; still I am thoroughly convinced that the impossibility of obtaining labor prevents a large majority of planters cultivating as thoroughly as they wish, and makes many of the palliative measures, I have to notice, present the same objection to the planter as a physician's recommendation to take Port wine and a nourishing diet does to an English country laborer.

8. But while scarcity of labor may be urged as presenting a bar to progress by improved cultivation, there are a number of subjects on an estate with which labor has little to do. Thus, to judge from their limited number in a few bungalows and their entire absence in the majority, books treating of coffee planting and allied subjects hold a very low place in the esteem of most planters, managers and assistants. It may be said of several works on coffee I have seen that they are but indifferent compilations, too often merely reprinting the more scientific portions of their contents from works previously published, and surcharged with detailed descriptions of practical operations that can be more readily acquired on the estate than in the bungalow; still these condemnations do not apply to all or to works of general science, many of which contain much that is of value to the planter. Text books on Agriculture, Agricultural Chemistry, Vegetable Physiology and Botany and Geology should be in the hands of every manager, and I now may add Mr. Graham Anderson's "Jottings on coffee and its culture in Mysore" which renders this report in some respects unnecessary.

In these days when science is divested of mystery and every subject has its primer, written so well and simply that all who will may understand, it is absurd for men with large interests as stake to be deterred from acquiring the elements of a science by a skeleton in the cup-board in the form of words of comprehensive meaning but uneuphoneous sound that science is compelled to use. I believe the predisposing causes of leaf disease to be many, and a planter whose ideas are expanded by the study of a variety of subjects bearing on the question will be more likely to find out and remedy the peculiar conditions affecting the plants on his estate than he who waits for the single panacea to be found by another before he stirs himself.

I had no difficulty in the great majority of instances in tracing the probable cause of the disease, and I have little doubt that the remedies suggested on the spot will be effectual in lessening the evil, still as I have already mentioned I had constantly to deplore the want of a record of what had been done and the general absence of data in the form of experiments and their results which prevented me from giving the positive assurance that is desirable. Thus throughout the whole of Coorg I could not procure a single analysis of soil, sub-soil or rock, consequently it is impossible to say with any degree of certainty whether the application of this or that special manure should most commend itself. It is true certain classes of rock approximate in chemical composition, but it is no less certain that locally an element usually found may be replaced by another, and thus a probable composition may be only misleading. Even if the analysis of the natural products of the land were attainable, there would be something reliable from which to start. But the knowledge that the matti tree (*Terminalia Coriacea*) when burnt is a source of lime, and that its luxuriant growth in a locality would indicate the presence of an amount of lime sufficient for its demand on that particular food, I could find nothing to guide me. The manager of one estate who hails from Ceylon, where the value of scientific cultivation has been recognized for some time, I found to be engaged in some useful experiments which will eventually, if continued,

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yield valuable results, and I shall note further on some records of generous manuring on a stony estate as a successful palliative, but beyond these two instances, I recall no real attempt either to test manure or superior cultivation by experiment or to record results.

9. With these preliminary remarks I pass on to notice in some detail the more valuable answers I have received to the questions distributed, noting only those throwing light on the subject.

10. Questions on the rain-fall—What is the average, the maximum and the minimum rain-fall, and the effect of an unusually heavy or light monsoon ?

In Coorg.

(*a.*) With an estate seven years old and a record extending over the same period and giving an average of 59·81 inches, a maximum of 62·98 inches and a minimum of 54·47 inches, no marked effect caused by extremes of rain-fall is recorded.

(*b.*) On an estate 18 years old on which a maximum rain-fall of 185 inches and a minimum of 119·71 is recorded, but no average given, the effect of excessive rain is—

"apparently none on leaf disease, but a large increase of black rot."

(*c.*) On an estate in the "Bamboo" district from 6 to 14 years old, with an average of 50 inches, the disease was found worse "after a light rain-fall."

(*d.*) On an estate 15 years old on which the average rainfall is 60 inches no conclusion is arrived at.

(*e.*) On an estate with a rain-fall varying from 250 to 280 inches and on a second under the same management giving 150 inches to 186, the following observations were forwarded :—

"An unusually heavy monsoon is very bad as leaf disease is very virulent under such conditions, a light monsoon has the contrary effect. I may state that from my experience an attack of leaf disease occurring in the monsoon is generally much worse than one in the dry weather. For instance with a heavy monsoon and an attack of leaf disease the crop is by that time already on the trees and on account of the heavy rain you can take no steps to mitigate it, and when the leaves are all finished off by it, it attacks the crop which drops. It then attacks the wood which turns black and dies. In a light monsoon on the contrary during a break you can apply manure and then the sun itself when accompanied by showers is a great cure for leaf disease. When the disease attacks the trees in the dry weather it generally occurs in February, March and April, and as in average cultivated land, it generally disappears with the blossom showers, it has not sufficient time to effect much damage, and as at the time manuring operations are always going on, the trees contrary to the monsoon time have it all in their favor."

In Mysore.

(*f.*) On an estate part of which is 50 years old, but the average of all the coffee trees might be put at 20 years, where the average rain-fall is about 70 inches, the maximum 80, and the minimum 50.

"The effect of a course of heavy monsoons is to diminish leaf disease, while a course of light monsoons is to increase it."

(*g.*) On an estate 14 years old the average rain-fall for 11 years has been 70 inches, the maximum 86, the minimum 47 inches—

"Heavy rain followed by close foggy and light misty weather creates and increases the disease very much. Heavy showers followed by bright sunny weather makes it disappear quickly."

(*h.*) On an estate about 30 years old average rain-fall 65 inches, maximum 85, and minimum 49 ; the superintendent writes :—

"In 1875 there was no leaf disease to speak of, but in November and December of last year I never saw it so bad. By this I conclude that as there was no disease to speak of in 1875, or just after a rain-fall of 85 inches, (the heaviest known for many years) together with what I have stated above that it was never so bad as last year, or just after the lowest rain-fall known, that is 49 inches, that rain-fall has great effect on leaf disease."

(*i.*) On an estate between 9 months and 40 years planted, with the average of 110·6 inches during 12 years, a maximum of 145·16 (in 1874), and a minimum of 92·61 (in 1878)—

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"Cannot say with any certainty *generally*, but in the special instance of the 1878 monsoon, which was the lightest I have ever gauged, it was followed by the severest attack of leaf disease I have known, which spread over the whole estate some two to three months earlier than it had on previous seasons."

(*j*.) On an estate 25 years old with an average rain-fall of 100 inches ranging between 80 to 120—

"I have found less leaf disease after a heavy monsoon."

(*k*.) From an estate 21 years old with an average rain-fall of 69·95 inches, a maximum of 85·81 and an average of 46·83 ; the following remarks were forwarded :—

"I am of opinion that the *distribution* rather than the total amount of rain-fall influences leaf disease. Heavy rain will not actually produce an early visitation of *Hemileia*, but decidedly favors its primary development. *Rot* "a concurrent associate," however actually arrives at *maturity* during heavy rain. In old land the point of saturation is arrived at very early in the monsoon. Complete saturation followed by one or two sunny days and supplemented by the occurrence of misty, dull and sunless weather, forms conditions highly favorable to the perfect development of the fungus ; and if such conditions be unusually prolonged, the bright orange-colored efflorescence changes both form and color and becomes a pure *white*, thick flocculent coating, closely resembling mildew. This change is particularly common in dense shade and in my opinion indicates that the disease has passed through a phase constituting further development. I believe this to be the stage of absolute maturity and points to the extraordinary robust health of the fungus under the peculiar local and atmospheric conditions above referred to. During the prevalence of the disease and immediately before its appearance, all growth of the coffee tree seems to cease. Heavy showers accompanied with thunder and lightning will pass leaf disease rapidly through its phases ; the coffee tree immediately begins to grow and will quickly throw off the disease, provided always that the intervals between the showers are bright and sunny. A return of murky weather will however reproduce the pest. In fact as far as I have seen I consider that if the disease is not actually produced by a saturated soil and atmosphere, together with a want of electricity, it is decidedly assisted and favored in its development by such conditions. Anything tending to facilitate the entry of air into the soil and thus keep up gradual decomposition of its organic constituents, appears to be inimical to the disease. * * * * *"

(*l*.) Again, another Mysore planter writes—

"Holding as I do, the opinion that *Pellecularia Koleroga* is only the forerunner from out of which *Hemileia Vastatrix* has its birth ; a heavy monsoon has the effect of increasing the former and as a sequence decreasing *apparently* the latter, on account of there being fewer leaves left for it to attack."

11. Although these answers may appear at first sight somewhat discordant, they indicate, when carefully looked into, one or two points of importance. Most of the answers quoted (which are all on which reliance can be placed) point out that the disease appears worse after a light or a series of light monsoons, and from personal inspection of nearly the whole of the estates from which these records were obtained, I can readily understand this.

12. A glance at the analysis of the soils of the only estate I am able to quote throwing light on this point shews that the effects of burn and only surface cultivation are most disasterous. Thus :—

	Virgin Soil.	After 10 years cultivation.
Organic matter and water of combination	27·60	20·00

The mechanical texture is very considerablychanged for the worse by the lessened amount of organic matter and its consequent inability to retain the same amount of water. The value of organic matter to soils I shall shew further on by statistics when discussing different mechanical operations advisable for coffee estates so that I need do no more than mention this point now. Through an indifference or want of knowledge of deep cultivation generally, and in particular cases from the shade being too light and the trees grown to afford it containing a large proportion of surface feeding species ; from a too heavy burn of what was originally light jungle, and the consequent destruction of organic matter in the soil ; these estates when subject to a short monsoon, especially if it be also light, suffer both from the injury done to the deeper roots by the contraction of the soil and also from the surface cultivation largely inducing surface growth, and the consequent retention near the surface of a large proportion of rootlets which in the dry weather are so burnt up as sensibly to diminish the vitality of the tree.

13. On the two estates respectively recording 100 and 100 inches as averages, both of which I visited, the difference in the amount of labor and manure bestowed fully accounts for the respective answers. The one has always been worked with ample capital and by an energetic manager and in consequence was a picture of health at the time I inspected it. The second although blessed with 12 inches of rain in excess of the other in the year of greatest drought, was one of the most disheartening pieces of coffee that came under my notice. Had it not been for the magnificent original shade it possesses, I have little doubt that every year of light rain-fall would have left as severe a mark as 1878, which the balance sheets would have shewn too indelibly to have escaped record.

14. Passing on to heavier rain-falls the testimony changes and becomes adverse. From the estates recording 180 to 250 inches and 150 to 180 inches, estates which I also visited, the large rain-fall proving injurious is not surprising. The coffee is generally planted on exceedingly steep slopes, and in very little soil most of the surface being rocky. The rocks are very friable and by their disintegration go far to keep up the fertility, but the steepness of the estates allows the rain to wash away a large amount of the finer particles of manure and soil as well as all readily soluble matters. Any means tending to make the water flow through the soil and to detain it without causing stagnation as well as frequent, even of necessity, light manuring may mitigate to a considerable extent the injury from the always high and often excessive rain-fall.

15. In dealing with the question of rain-fall and the influence it has over coffee growing over a large extent of country, generalities only can be discussed. As one gentleman in answering my questions rightly points out, the distribution rather than the total amount is that which most influences the disease. Thus the length of time the land is saturated, concomitantly with an atmosphere abundantly charged with watery vapour, is as much to be dreaded as the prolonged draught of the rainless months. I presume there are no planters who do not at times regret the extreme wetness of their land during the heavy monsoon rains, and they no less object to the stony hardness the surface too often assumes after the heavy rains have passed away. A method to get rid of surplus water at one time and prolong a period when the land is neither too wet nor too dry, has consequently been a desideratum. This desideratum may, in a great measure, be met by deep drainage on all lands where the slope does not exceed 25° to the horizon, followed by deep cultivation; but on steeper land it is, I fear, impracticable. Such a course will give to the plant an extension of time when favorable conditions for its healthy growth occur, and also afford the planter an opportunity for the prosecution of manurial and digging operations. I believe that of the numerous suggestions for the mitigation of '*Hemileia Vastatrix*' none will be worthy a more careful trial on the majority of estates in Southern India than deep drainage combined with deep cultivation, as not only will it offer antagonistic conditions to the favorable development of this and other fungoid diseases, but it will act positively in the oxidation of the soil and its mechanical improvement, and thus afford a more healthy and enlarged feeding ground for the roots of the coffee plant. With one exception sub-soil drainage has not been tried locally in Mysore or Coorg on coffee estates except locally to get rid of a stream or dry up a swamp, as the answers I have received to the question on this subject are generally that it is unnecessary or untried. In the one instance I have received the following reply which my own observation on the spot corroborates:—

"My experience in deep draining is very limited with the exception of actual swampy land. I however as an experiment deeply drained the crest of a hill on purpose to see the effect of growth and influence on leaf disease. The result was most remarkable, the coffee trees remaining beautifully green through the hot weather. Leaf disease did absolutely no damage, and I am confident that all exposed and poor hill tops would be greatly benefited by deep closed drains if other operations of culture were also carried out."

I have mentioned that a deep draining of a soil is the means by which excessive or stagnant water may be got rid of. Thus at all times there is a level in the soil at which water stagnates. At low levels this is always tolerably near the surface, but elsewhere any rock clay bed or other impervious strata may cause the water to remain at a high level. This level naturally sinks in the dry season and rises in the wet, and it becomes harmful to the coffee plant when it is so near the surface that the roots are submerged in it or in a layer of soil immediately above it rendered unduly moist by capillary attraction. A shower of rain falling raises the level of stagnant water which, unless there be an outlet, approaches nearer the surface until it finds a means to overflow just as pouring water into a barrel will cause the water inside to flow out of the lowest opening. Stagnant water is injurious in many ways to cultivated plants. Mechanically it lowers the temperature of the soil by radiation. As soon as the upper layers of water in a surcharged soil have become cooled by radiation they sink, as cold water is heavier than

warm, and warm water rises to supply their place ; thus cooling first of all the surface of the land and afterwards the deeper portions. Thus a loss of temperature of 6·5° F. by this means is equivalent to a rise in elevation of nearly 2,000 feet above the level of the sea, or to put it another way, if the sun have to evaporate 30 inches of rain-fall a year, it is equivalent to the daily burning of 1 cwt of coal. Besides lowering the temperature of the soil and thus lessening oxidation, stagnant water in causing the soil to be cool, prevents warm air passing over it exerting any useful influence, as the conducting powers of water are so poor that it gains little in temperature from its contact with heated air : consequently a formation of mist or fog over the saturated land ensues highly favorable to the growth of the fungus and its rapid extension over stem and branch.

16. Further, undrained soil when it dries is in a very different mechanical condition to what is desired. It has a hard baked surface on which the passing wind bestows no moisture, and it presents a hard impenetrable surface to the pick-axe which every cooly on an estate should be wielding in dry weather. A hardened surface further causes much of the valuable rain falling in the early blossom showers to be wasted, as what we want rain to do then is to penetrate out of the reach of the heated air and descend to the roots of the plants ; not to spread about on the surface to be licked up again by the passing breeze.

17. With the soil full of stagnant water every addition from the clouds in the rainy season means an overflow and mechanical injury to the surface. If water cannot pass freely through the soil, it has to find its way to the lowest level on or near the surface, and in its passage carries with it the finer and lighter particles of the soil and valuable fertilizing matters in a state of solution. Hence drainage lessens wash even on the steeper portions of estates and prevents the rapid exhaustion of manure. I believe soils on which the fine primeval forests of Southern India have through ages accumulated large amounts of humus on the surface of the land not unfrequently contain organic acids in injurious amount, and the presence of leaf disease in young nurseries which has occurred even with selected seeds may be traced to their too hasty formation that does not allow sufficient time for soil exposed for the first time to become thoroughly oxidized. In support of this, I may instance an estate where the nurseries were formed on deep red soil. Some portions of the land had been exposed for two seasons, others only for one, and the difference in the growth of the seedling plants was enormous. Those on the older aerated land appeared months in advance of the others and were healthy and vigorous, while others presented a weak stunted appearance and a less healthy foliage. I have seen a similar want of oxidation in a marked degree on the deep red loams met with here and there in the Malnad taluks of Mysore on knolls which the ryots never cultivate. Such soils are probably exceedingly rich in plant food, but it can be rendered available for plants only by lengthy oxidation, and the continual fallowing which would effect this is beyond the means of the Indian ryot of to-day But introduce a system by which the oxidation of the mass of the soil is brought about and new and favoring influences are called into play. The injurious half decayed humus mixed with salts of iron and organic acids probably combined in injurious compounds is introduced to the life-giving oxygen of the air. Half-formed humus has an opportunity to become thoroughly decayed and evolve carbonic dioxide and ammonia presenting to the plants foods instead of poisons. The iron present in such marked excess in the soils of the Mysorean plateau is rendered free to perform its legitimate function of giving up the oxygen demanded by vegetation, while it gathers fresh stores from the atmosphere. Sulphur, which as a sulphide or compound insufficiently oxidised is hurtful, has a chance of becoming a sulphate and thus a healthful ingredient in the soil.

18. But to continue the objections to the presence of a saturated soil. As nature does not permit a vacuum, the subsoil water as it descends in a properly drained soil drags air after it, and the powerful influences which oxygen exerts on the soil can come freely into play. Thus in a *moist* soil in a well pulverized condition in which the interstitial canals are filled with air and water, the former will occupy one-fourth of the entire bulk. Consequently a well drained estate with the upper eight inches of soil in a fine mechanical condition will retain beneath its surface the large amount of 12,545,280 cubic inches of air per acre.

19. Although we commonly only talk of the oxygen of the air as being a valuable agent, it must be remembered that air contains other gases in small amount, and that these are washed into the ground by rain. These are carbonic anhydride, nitric acid and ammonia, and these useful solvent agents are utilized by the soil in the decomposition of the silicates which form so large a proportion of its bulk.

20. The advantages gained by drainage in ordinary agriculture are numerous, and many can be shared by the planter. Grass land is always found to throw a sweeter and finer quality of herbage, while sedges, rushes and other marsh plants disappear. The soil free from stagnant water and abounding in

though I passed over much where shallow stirring caused a ready descent of the soil down a hill side when walked over. I have heard deep cultivation deprecated on the ground that it increased wash, but it appears to me that deeply cultivated land, under which no hard layer of earth that would stop the water penetrating is to be found, affords a larger bulk of soil for rain to penetrate before the point of saturation is arrived at ; consequently the surface soil will not so rapidly become charged with water, and in a condition to cause a landslip. With the land in a state in which oxygen can freely penetrate the burial of weeds and loppings of trees by regularly digging or pickaxing them in equally over the land on which they are strewn is to be recommended. The difference in effect between sparingly distributing decomposing matters in an aerated soil and burying them in bulk in closed pits is enormous. In the first case decomposition is hastened, in the latter retarded. I may here quote *in extenso* the pertinent remarks on this subject of a thoughtful planter appended as a supplement to his replies.

" In addition to answering the questions put, I think it advisable to state my opinion that we have ourselves to blame to a great extent for leaf disease, whether in the form of rot or red rust, and assuming for the sake of argument that they are different entirely, then I think that we have in the first place created rot by a system of burying in pits all green weeds and decaying vegetable matter, and by a practice which obtained very largely some ten years ago in Mysore of scraping into the holes made for planting as much fallen leaves as possible: the after-effect being, especially where the holes had been filled in wet weather, that the top of the hole or covering of earth caked when dry weather set in, the vegetable matter in the course of time being combusted, occupied a less space, and a water lodgment took place. I recollect in 1869 when going over a piece of land that had been planted by my predecessor to find out the places where the holes had been, in order that I might find where to put in supplies, that the coolies tapped the ground and could tell immediately by the hollow sound where the hole was, and in the generality of cases there was a crust of some two or three inches of earth and below that a cavity a foot deep. I believe I am right in saying that the native gardens of Mysore were not *generally speaking* attacked with rot, till some years after it had been season after season on European holdings. The natives never took holes and hermetically sealed up weeds, leaves, &c., in the process miscalled 'weeding and burying.' I think I am right in saying that the observations of rot and the serious anxieties it caused, preceded red rust by some years. When I came to Mysore in 1868 rot was ravaging many a fair field of coffee, but it was not until 1870 that red rust began to be talked about in local circles, and in 1871 it had increased so much that in company with a brother planter I found on examination under a microscope that it was of fungus growth. Many of us then knew that rot was of fungus growth, but many also ignored the fact and insisted that it was caused by drip and want of handling, forgetful of the fact that it was a *new thing* as a pest on coffee trees, whereas neglect of handling and drip were then old stories on many properties."

30. The positive value that cultivation has in promoting a large amount of air in the soil and the value of the latter on the growth of plants has been proved by the experimentalist Stockhardt thus. He filled two cylindrical glasses measuring 2·5 ft. in height and 5·5 in diameter each with soil. In each cylinder was sown 5 grains of oats and 3 of peas. One cylinder had a hole in the bottom connected with a gasometer filled with atmospheric air. The other received air only from the surface. So the first was given daily during the period of growth from June 14th to October 3rd, 100 cubic centimeters of air. The soils in both cylinders were of the same quality a loamy sand rich in humus. The out turn of dry plant substance was as follows:—

	Without additional supply of atmospheric air.	With additional supply of atmospheric air.
	Grammes.	Grammes.
5 Plants of Oats	3·90	7·65
3 Plants of Peas	1·72	2·46
Roots of both	0·27	0·38
Total.....	5·86	10·49

Or twice the amount of plant substance where an abundance of air was procurable.

The trenching to which I have alluded offers a valuable means for causing the atmosphere to readily penetrate the deeper layers of the soil and no obstacle to the rapid passage of water beneath the surface, but pits made to bury weeds or any excavation that is not continuous and inclined must exert a well-like action in retaining water. The injury caused by stagnant water I have already discussed, but its injuri-

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ous action is intensified when it meets with a mass of succulent vegetation buried in the soil. In recommending the digging in of weeds and debris I presumethe former are attacked before they have seeded.

31. On light sandy soils, "green manuring," that is the covering in of a crop grown specially for the purpose before it has matured, is a practice much to be recommended, and is, in some parts of Europe, largely resorted to to improve the land. The crop in growing acquires mineral matter that on its subsequent decay is again liberated in a form that can readily be re-used by other plants. The crop also adds to the soil the carbonaceous matter it has acquired from the atmosphere and the nitrogenous products it has built up in its tissues. The quicker the decay the quicker the return to the soil. Viewed as green manures annual weeds assume a new aspect, but only when kept in hand by abundant labor can they be regarded as servants. The growth of other plants that can be kept more easily within bounds, such as the various species of gram, especially horse gram and green gram, commends itself to the attention of those who from a too complete burn or other cause require an addition of vegetable matter to their land.

32. I have now to devote a short space to the consideration of the value of humus in the soil. First as to the changes it effects on the oxygen contained in the interstices Herman made the following useful experiment to test this point. He brought 28 volumes of wood that had commenced to rot under a bell jar which contained 262 volumes of air. The wood remained under the globe for 10 days at a temperature of 80° F, after which time thougli the volumes of air remained the same it contained less oxygen and more carbonic anhydride thus:—

	Before the experiment.	After the experiment.
	Volumes.	Volumes.
Nitrogen	207	194
Carbonic anhydride	Nil.	40
Oxygen	55	28
Total.....	262	262

The value of carbonic anhydride in the soil as a solvent I have already pointed out.

33. The next point of importance as a effect of humus in the soil as a power of extracting moisture from the passing air, a matter that has lately been well investigated at the Government Farm, Sydapett, Madras. The following figures extracted from a very complete report on the subject may be sufficient for our purpose.

34. Table shewing the action of humus on soils.

	Soil No. 1. Black cotton soil.		Soil No. 6. Light sand.	
Air dried soil contained percentage of water	9·43		·92	
Do of organic matter	5·46		1·90	
Do of absorbed	...		...	
Moisture after exposure in a saturated atmosphere	5·06		·19	
	Pure.	With 5 per cent organic matter added.	Pure.	With 5 per cent organic matter added.
Took up from the air liquid water per cent	34·67	40·16	22·92	31·10
Retained liquid water after exposure for 336 hours, per cent ...	17·83	22·12	2·62	10·39
Liquid water equal to rain-fall in inches	2·35	2·72	1·74	2·36
Time required for absorption, hours	8·25	9·50	·75	1·50
Increase or decrease of bulk on saturation, per cent	+8·33	+3·33	−8·33	−1·66

35. It will be noticed that a clay soil containing naturally 5·46 per cent of organic matter was able to take up 34·67 per cent of water from the air against 22·92 taken up by a sandy soil with only 1·9 per cent or a difference of 11·75 per cent, most of which is due to humus. The addition of 5 per cent organic matter improved the absorptive power of a clay soil 5·49 per cent and a sandy soil 8·18 per cent, so that the lighter and poorer the soils, the greater is the necessity for them to be rich in organic matter. It was found in another series of experiments that when 25 per cent of organic matter as mixed with light soils their power of absorbing moisture when exposed at night was nearly twice as great as when in their natural condition, whilst in the case of strong clay soils a similar addition only caused an increased absorptive power of about 5 per cent. Soils usually found on coffee estates are not nearly so extreme in action as these nearly pure clays and sands, and it may be taken as a rough guide that if the addition of organic matter does not increase in a marked degree the retentive power of a good soil, its physical composition is in this respect all that could be desired.

36. A curious point to notice in these experiments is the comparative decrease in bulk on saturation. An addition of organic matter to a clay soil lessens its power to increase in bulk on the addition of moisture, but with sand the opposite effect is observed. Five per cent of organic matter in the latter case causing a shrinking of only 1·66 per cent instead of 8·33. Thus the presence of organic matter exerts a neutralizing action and prevents clay soils expanding only to crack on drying into large block separated by gaping fissures, or sandy soils shrinking suddenly when a heavy fall of rain occurs leaving surface feeding roots suddenly exposed. Humus is especially valuable to surface soils. If these be rich in clay and this be in a finely divided state, heavy rain or the "drip" from forest trees or heavily grown shade causes it to assume on the surface a plastic condition, thus closing the lower layers the access of air. Moreover the upper layer of clay will on drying speedily be baked into a hard cake-like mass through which the next fall of rain will not readily pass, and then the liability to wash will be increased, while the fertilizing action of rain water flowing through the soil will be lost. I cannot express too strongly even at the risk of repetition the necessity of an open soil, especially in India, where for so many months little or no rain falls. It must be remembered that plants may exhale from their leaves as much as seven times as much water as they receive by rain, so that eighty per cent of this must somehow or other be absorbed from the air.

37. In the hot weather, a soil deeply stirred and in consequence cool from the interstitial water it contains, will lower the temperature of the air above it and cause this to part with the water it cannot so readily hold as vapour, when impinging on a surface with a lower temperature than its own. This action will be greatest at night and in places where radiation is not impeded by over hanging shade so that the growth of trees that close their leaflets at night would, provided they are suitable in other respects, be a point worthy the attention of the planter.

38. Lastly, we have to remember the value of humus in retaining water both for a long period of time and to a large extent. Pure humus will retain with a sponge-like tenacity twice its own weight of water, while sand saturated to its fullest extent will only retain a fourth of its weight. Clay stands between the two. The value of humus in increasing the retentive power of soils is thus much more powerful than that of any other agent. A glance at the foregoing table confirms this. While sand with 1·9 per cent of organic matter was only able to retain 2·62 per cent of its weight of liquid obtained from the passing breeze, an addition of five per cent of organic matter gave it the power of subtracting 31·10 per cent and retaining 10·39 per cent of this after exposure for 336 hours. Similarly strong clay land by the same addition was able to retain 4·29 per cent extra.

39. Question.—Was the original jungle on your estate burnt or rotted ?

This question was asked with the view of ascertaining whether the considerable diminution in organic matter that must take place in the surface soil by burning a primeval jungle in its entirety produced any marked effect. Although I am unable to give figures or quote replies of any value, I found a growing belief that the "good burn" considered so essential to success years ago, is not the unmitigated blessing it was at one time considered to be. I visited estates where the shaken belief in the excellence of burning every thing at once had given place to the opposite extreme of burning nothing ; to burning the underwood only and felling the large trees and leaving them to rot ; and to thoroughly clearing patches while broad belts were left with the timber untouched and only the underwood cleared away, so that shelter might be afforded from strong winds. Local peculiarities must largely determine which course is the best to follow, but planters will do well before applying the fire stick to consider the arguments and figures I have brought forward in support of the value of organic matter in the soil, and

remember that once dissipated the large amount yielded by the original forest if permitted to rot cannot be again accumulated. Again, it is important to observe that plant ashes contain soluble salts in large amounts and these, though the soil retains them when contained in water passing through it, may be washed away over undrained land if left on the surface in large amount before the plants can assimilate them. Small plants of course cannot absorb so large an amount of food as large ones, and if the valuable constituents present in jungle growth be suddenly set free by burning to be dissipated by surface wash, the young coffee plant put down on the clearing as it grows and requires a constantly increasing quantity of food finds instead a constantly decreasing supply. I may here insert as bearing on the subject two analyses of Coorg jungle wood-ash, one freshly burned, the other burnt several years before and exposed:—

	Fresh jungle ashes.	Long exposed jungle-ashes.
Organic matter (chiefly charcoal) and water of combination ...	31·60	32·50
Oxides of iron and alumina	5·25	4·15
Calcium carbonate	24·34	18·25
Magnesia	2·50	·85
Potash	3·28	2·26
Soda	·40	...
Phosphoric pentoxide	2·12	1·20
Sulphuric trioxide	·80	·45
Silica	29·63	40·34

It will be noticed on looking through these analyses that in every case the more urgently required constituents have seriously decreased in quantity. The comparative cessation in growth, which I have frequently heard complained of as occurring in young coffee after it has grown rapidly for a couple or three years, may be due to the exhaustion of these constituents added to the soil by the burn, and the necessity for the plant to develope an increased root surface to acquire from the more slowly yielding soil with greater difficulty its necessary food supply.

40. But if instead of burning the jungle be allowed to rot, the setting free of soluble salts from the decaying vegetation becomes a gradual instead of a sudden process, and a large surplus is not thrown suddenly on the mercy of the heavy monsoon rains. In addition the organic acids present can act on the silicates in the soil and form slowly but uninterruptedly more soluble combinations.

During my tour I visited a young estate in Mysore on which, what I believe will be found to be in the main the best system of opening out was being carried out with highly satisfactory results.

41. The underwood was first cleared, but the thorny bushes alone were collected into heaps and burnt. The jungle was then thinned, the useless trees being carefully felled so as to form the smallest possible obstruction and to leave if any thing an excess of shade. Coffee and where requisite shade were then planted simultaneously, and the land deeply pickaxed over. A second thinning to the jungle was then given, the young coffee being injured to an inappreciable extent by the falling trees and these were left on the surface to rot. As the weeds had never been allowed to get ahead there were few to be seen, and at the time of my visit when much of the estate was giving its first crop, a very heavy one, the loppings of the jungle trees were far advanced towards decomposition and formed at once a shade to the land exposed between the rows of young coffee and a mat through which weeds did not readily spring. The trunks of the large trees lying about were also rapidly decomposing and yielding a store of humus such as can be obtained in such quantity in no other way. The exigencies of limited labor had also led to a novel, but under the circumstances a commendable method of manuring with cattle manure. This in a fresh state could be obtained in large quantity, and the question whether it was better to cover large areas with fresh manure diluted with large amounts of litter and derive the partial benefit only obtainable by this means, together with the choking action it exerted on weeds, or to prepare and dig in a small quantity of thoroughly rotted manure over the limited area the amount of labor permitted, was answered by the first named method. The estate was hilly, the soil generally shallow and gravelly so that cool manures and the bulk of organic matter thus supplied admirably met the special peculiarities of the lands.

42. Question.—What is the age of the plants most commonly attacked?

In Coorg.

"All ages," again "all ages," "from three years upwards," "at any age."

In Mysore.

"Plants of all ages are attacked. Every year since I introduced Coorg seed, plants when taken from the nursery have been affected. They in almost all cases after they have been planted for some six months seem to throw off the disease entirely, or to such a degree as not to be noticeable except on close inspection, nor does the disease again affect them until they give their maiden crop or just before in cases in which plants are bearing very heavily. As far as my experience in Coorg plants goes they are never affected to such an extent as to cause serious loss of crop or wood; the attack in the nursery seems to be the only injurious one *at present* as it stops the growth of the plant for a month or so after transplanting which should not be so with healthy and well-planted plants. I say at present because I feel sure that the Coorg plants if neglected, would soon shew loss of both crops and wood. The "Chick" on the other hand I don't remember to have seen attacked in the nursery, but from the time they gave their maiden crop they are attacked yearly and most of them twice a year, each attack destroying both crop and wood. I put my loss of crop on "Chicks" down to nearly one fourth."

"Of all ages, but perhaps preferably (but not very markedly so) with the oldest and the youngest."

"Age of tree attacked, very old. Of young trees I had one line the branches of which, on one side, hung over a *weedy, deep, moist, nullah.* The whole of these branches were so badly attacked with the leaf disease that the whole of them died back, and strange to note the branches on the same trees, but on the opposite side, were free from leaf disease."

"Plants of all ages seem equally liable to the disease."

"My estate is too young to shew any symptoms of the disease; my oldest "Coorg" plants not yet being three years out. There were however some old plants on my arrival here, but these had been burnt a year previously, the shoots that came up subsequently were very feeble and would not, I am certain, be any criterion for guidance. However these have shewn leaf disease strongly during the past two years and fungus in abundance on every tree without exception. I have none on Coorg plants so far"

"The disease whether in the form of *Rot* or *Red Rust* is quite impartial in its attacks. I have seen it of both forms on two leaved seedlings. I however never observed *Red Rust* on two leaved seedlings until last autum when transplanting to the permanent nurseries, and my doing so was another link in my chain of argument as that particular seed nursery had just previously been very seriously injured during the prevalence of the monsoon rain by rot."

43. Some of these answers are of considerable interest in throwing light on the subject. Generally it will be observed that plants of all ages are attacked, and that any condition tending to check vitality is favorable to the development of the disease. Thus in the first case quoted from Mysore, Coorg plants are noticed to suffer when first taken from the nursery, though they recover in a few months and do not again become attacked until they yield a maiden crop. Perhaps in this instance the check to growth is a fault in transplanting such as the transfer from a too highly manured nursery to comparatively poor land which not noticed by the more lethargic "Chick" affects the sensitive Coorg. Or it may be the estate is more exposed than the nursery, the pits insufficiently dug or drained, the plants not put out in ball, or in a ball too tenaciously pressed together. As the Coorg plant has in its young stages a much quicker habit of growth than the "Chick" variety and has, as it were, every organ stretched to the utmost in prosecuting growth, a check by which the rootlets were injured or impeded in their action would act with a greater severity. On the other hand its inherent vitality favored by a condition of soil that appears to occur most strongly in Mysore, enables it to develop new rootlets and quickly regain an equilibrium. This habit would seem to continue in force throughout the entire life of the plant as the Coorg, in its old as well as in its young stages, resists the disease more successfully than does the older and more feeble "Chick." The tendency of very old or very young trees to shew the disease somewhat more fully than those of a medium age noted in one case is, I believe, due in the case of old trees to the extreme age of many of them on the estate from which the answer was sent. I am not aware to what age coffee grows in a natural condition, but that the period of its full vitality can be shortened by excessive and ill-timed pruning, by indifferent cultivation and neglect of manuring there can, I think, be no doubt.

44. Another answer is instructive in shewing the injury resulting from the obstruction to free ventilation and presenting favorable conditions for possible infiltration by the leaves. I noticed on several estates where insufficient labor had caused patches of weeds to be left, a decidedly greater virulence in the

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attack of the disease, partly due to the want of cultivation, but also in part to the leaves and twigs suffering from an insufficiency of light and air.

45. An interesting instance is incidentally introduced in one answer of the uselessness of burning which deserves attention, as during a recent visit to Australia I was consulted on this subject by a planter from Fiji, where the authorities propose to extermine leaf disease by burning the coffee estates on which it has appeared. The latest information I have received in answer to my question—"Whether it was by a strong fire sweeping all before it that the estate was burnt, or by little smouldering heaps"—received the following answer :—

"I beg to inform you that though not very intense the fire must have gone through the whole sufficiently strong to burn the foliage and thin bark of the coffee bush. It may be better imagined than described when I mention the probable state of the garden in March. Dropped foliage of trees and cut weeds (native system of weeding) beneath, the whole perhaps from four to six inches thick. The crisp leaves burn well but not by a strong flame when so thinly spread. In one corner a few hundred bushes remained untouched by fire, but I feel certain these did not tend to develop the leaf disease to other bushes at a distance of perhaps one thousand yards or more and no bushes intervening. Since I wrote my "answers" referred to in your letter I have nursed many of those "feeble shoots" into very fine bushes but tinged with the leaf disease strong enough to convince me that burning of the entire place will not remove the pest."

46. I may here touch on a preventative measure which is worthy of much more general use than it has yet received at the hands of planters generally, first because of its known value in agriculture and secondly because experiments as far as they have gone shew its value in the particular enterprise of coffee planting. I allude to the importance of obtaining a change of seed. In obtaining seed from a distance it is imperative that it should also be the best of its kind, and it has been found in the case of cereals to increase in weight if transported from a warmer to a cooler climate. Its manipulation requires care, and all imperfect and small seeds must be carefully removed. Mr. Graham Anderson's directions on this subject on page 50 of his admirable "Jottings" (obtainable at the Caxton Press, Bangalore), are those which he as a practical planter has found successful. I have only to add to his remarks that healthy seeds obtained from healthy plants grown on a poor soil and under adverse atmospheric conditions, so that their production by the plant proves its robustness, are preferable to seeds picked from a plant thriving in a naturally rich and highly manured soil. It is well also should seed be required on an estate with somewhat light soil, to obtain it from another where clay predominates, and *vice versa*. Again, seed should in preference be picked from mature trees avoiding either extreme in age. However perfectly seeds may be cleaned from the pulp it is advisable they should undergo a pickling process. A useful pickle is putrid urine into which the seed coffee may be immersed in a basket and stirred about, so that any light berries may float and be skimmed off. Another pickle may be 2 lbs. of blue vitriol, sulphate of copper, dissolved in a gallon of water. A third Condy's disinfecting fluid diluted with water. After withdrawing from the pickle the berries should be dried in fresh wood ashes or lime, and kept in ashes until required. I believe it would be a benefit to the planting community generally if a planter in each District devoted particular attention to the proper selection, and preparation of seed for supplying demands from other quarters. In support of my suggestions I quote an illustration of the value of a change of seed from the Ceylon Observer of December 24th, 1878, sent to that paper by a Mysore planter.

"Another instance of comparative immunity in young plants from leaf disease:—When I took over charge of these estates on June 1st last year I found the nursery on one estate for the monsoon operations quite inadequate, but another nursery had been put down in the month of April from seed got from a neighbouring estate that was planted with seed direct from Coorg. These plants though small were well grown for their age and I directed them to be planted out in ball. Some of them were put out so late as the end of October last, and none of them at the time of planting had any primaries on them. They may be said to be virtually free from leaf disease and what few plants have been affected have invariably been found on removal as to examine why, to have something wrong with them, irrespective of leaf disease. This instance I consider even more conclusive than the one on my own estate, though the result of an accident in the shape of the failure of the seed supplied for the first nursery, *because* these very young plants were all put out as supplies in an estate which has during the present season suffered very much from a bad attack of leaf disease, and whilst the old plants were covered with the red rust, *these young* plants were free from it. Even in plants only once removed, so to speak, or resulting from seed directly imported, that may be attacked, I have observed that the disease has not the same hold on the plant, and that in the majority of cases, although the fungus may settle on and attack a plant, it eventually *dies off, leaving a hole in the leaf.* This would go to shew that the body acted upon had sufficient initial vitality or strength of constitution to resist the epidemic, and if I am right the moral would be, never plant seed from your own estate or your own district, but get it from the healthiest coffee you can hear of at a distance of at least ten miles and if possible grown at a different elevation. It is further interesting to remark that in both the instances given above

of plants from seed twice changed, the seed at the second change *did not come from plants free from disease*, though the plants the seed was taken from were healthy looking, and from their being raised from imported seed had comparatively slight attacks of the disease."

47. I was much struck in my tour through Mysore with the difficulty experienced by planters in raising supplies. In some cases the old "Chick" variety refused to exist, in others it just lived, while vacancies filled with "Coorgs" had them in a flourishing condition. This is due to a difference in the requirements of the two plants, one perhaps being a potash feeder, while the other prefers lime. By this it must not be understood that a plant absorbs one to the exclusion of the other, but that conditions being the same one plant will in preference absorb one to a greater extent than the other. Should this be the case it is easy to understand that if, as is probable, both be present in small proportion and a former tree has absorbed one, say lime, in quantity year by year, and left the store of potash comparatively untouched; a second tree of the same kind planted in the same place can but send its roots into a semi exhausted soil and seeking in vain for a sufficient supply for its requirements allow the plant to perish. But if instead of a lime feeding variety, one preferring potash be planted, its rootlets at once find abundance of their chief food and sufficient of those for which the demand is smaller. To secure vigor of development must be a first consideration, and it has been proved that vigorous plants contain more alkalies than weak plants when grown under similar conditions; thus in the instance of oat plants the analysis of the ash under different habits of growth was as follows:—

	Vigorous.	Medium.	Weak.
Silica	27·0	39·9	42·0
Sulphuric trioxide	4·8	4·1	5·6
Phosphoric pentoxide	8·2	8·5	8·8
Chlorine	6·7	5·8	4·7
Ferric oxide	·4	·5	1·0
Lime	6·1	5·4	5·1
Alkalies *viz.*, Magnesia, Soda and Potash	45·3	34·3	30·4

If, and until we possess the necessary analyses—it can only be supposition—if for instance our soil for some reason contains only sufficient alkalies to permit the plant to extract 30 per cent of the weight of its ash, whereas if conditions were favorable it would extract 45 per cent, it can readily be understood that the plant only carries on a languishing existence. That it is probable that different varieties of coffee plants contain varying amounts of ash constituents, due to the partiality of each variety for a large proportion of some one or other food, may be shewn by the subjoined example of the analyses of the ash of five different varieties of potatoes grown under similar conditions:—

	I.	II.	III.	IV.	V.
Potash	69·7	65·2	70·6	70·0	6[illegible]·1
Sodic chloride	...	...	...	...	2 5
Lime	3·0	1·8	5·0	5·0	3·3
Phosphoric pentoxide	17·2	20·8	14·9	14·4	20·7
Sulphuric trioxide	3·6	6·0	4·3	7·5	7·9

Or to take a case with still greater extremes, it has been found that the ashes of wild asparagus and cultivated have soda and potash replaceable to a remarkable degree, thus:—

	Wild asparagus.	Cultivated asparagus.
Potash	18·8	50·5
Soda	16·2	...
Lime	28·1	21·3
Magnesia	1·5	...
Chlorine	16·5	8·3
Sulphuric trioxide	9·2	4·5
Phosphoric pentoxide	12·8	12·4
Silica	1·0	3·7

To shew how readily a plant will take up different constituents when they are added to a poor soil in the form of manure, and how indirectly some of these manures act, will be seen by the following experiment by Wolff on the straw of buckwheat :—

Percentages of ash in plant with—	No Manure.	Manures added to soil.			
		Salt.	Nitre.	Magnesic sulphate.	Calsic carbonate.
Potash	31·7	21·6	39·6	28·2	23·9
Potassic chloride	7·4	26·9	·8	6·9	9·7
Sodic chloride...	4·6	3·0	3·2	3·4	1·7
Lime	1·7	1·9	3·3	4·7	4·2
Sulphuric trioxide	4·7	2·8	2·7	7·1	3·5
Phosphoric pentoxide	10·3	9·5	6·5	10·9	10·0

49. These analyses are useful as shewing how the composition of the ash of the plant is influenced by its health and vigor, by the variety of plant, and by the substances with which its feeding roots are brought in contact, all points of interest to the planter. It has also been proved by experimental elucidation that the ash varies in proportion in different stages of growth, and generally diminishes as the plant grows old, and that of all parts the seed varies least in composition. For vigorous development the ash ingredients cannot fall below a certain amount in proportion to the total weight of the plant, though a plant may contain in addition to its necessary ash constituents a considerable extra amount which is unessential and accidental. Continuing the subject I subjoin analyses of Mysore coffee beans and also the soils on which they have been grown :—

The variety of coffee analyzed is the " Chick" :—

Proximate composition of the Raw " Chick" bean.	*Names of Estates.* S.	C.	B.	A.
Water	11·50	11·73	11·75	12·35
Cellulose	38·37	39·00	38·70	37·60
Glucose, Dextrine	16·50	17·00	17·80	15·80
Fat	15·00	15·40	15·45	16·00
Legumin, caseine	14·00	12·30	11·55	13·54
Caffeine	·90	·77	·75	·85
Ash	3·73	3·80	4·00	3·86
Ash.				
Soluble in water	75·00	482·50	80·00	85·00
Insoluble in hydrochloric acid ...	·90	·80	·70	·40
Composition of the Ash.				
Potash	59·14	59·10	58·00	58·50
Lime	6·10	7·84	7·80	6·16
Magnesia	7·70	7·03	7·00	6·84
Ferric oxide	·25	·32	·60	·27
Sulphuric trioxide	2·41	2·85	2·50	2·76
Carbonic dioxide	12.53	12·42	14·00	12·47
Phosphoric pentoxide	10·97	9·60	9·40	12·50
Silica	·90	·80	·70	·40

Analyses of the unmanured soils of the estates.	S.			C.	B.		A.
	Rich-mullah.	Virgin soil.	10 years under coffee.	10 years under coffee.	Sandy portion.	Average 10 years under coffee.	Over 10 years under coffee.
Moisture	3·00	2·53	2·13	2·57	1·40	2·93	2·35
Organic matter or water of combination ...	29·20	27·60	20·00	10·10	5·13	11·77	13·85
Silica	37·70	40·70	48·77	59·80	87·50	55·35	57·22
Oxides of iron and alumina, (chiefly the former) ...	28·20	26·90	27·60	26·40	4·80	28·80	25·50
Lime	·60	·90	·40	·32	·20	·35	·27
Sulphuric trioxide	·27	·23	·25	·19	·09	·22	·20
Magnesia	·33	·38	·30	·23	·10	·24	·18
Potash	·48	·45	·35	·25	·05	·20	·26
Phosphoric pentoxide	·22	·31	·20	·14	·03	·12	·16

50. These analyses are of great interest as a complete set. Compared with other coffees that marked S is remarkable in its high percentage of caffeine and for selling higher in the European market than that of any other estate. The whole of the varieties shew a high percentage of fat and legumin. The composition of the ash shews an exceedingly high percentage of potash, exceeding Ceylon coffee in this respect by 4 per cent, but the richness of the soil in this constituent probably causes potash to be taken up largely. Indeed so rich are these soils in all plant constituents, that I do not wonder at a remark in a letter accompanying the analyses. "Hardly any manure is used on our estates here." Yet though rich the plants they support have not escaped leaf disease, chiefly I think through insufficient cultivation being given. As a useful comparison I append four analyses of the soils of some Ceylon estates condensed from the "Ceylon Observer."

	Fairfield.	Mansaella.	Trallawakelle.	Galkandewalle.
Moisture	2·98	3·70	7·30	5·95
Organic matter and combined water ...	13·85	12·75	13·98	13·44
Silica (given as silicates) *	57·00	57·85	53·84	58·52
Oxides of iron and alumina ...	25·59	31·39	23·80	21·36
Lime	·08	·05	·08	·13
Sulphuric trioxide	·09	·10	·09	·09
Magnesia	·17	·07	·18	·11
Potash	·09	·07	·11	·17
Phosphoric trioxide	·11	·10	·11	·09

51. A comparison of the two sets will no doubt recall the remark of a planter in the earlier portion of this report to the effect that while Ceylon requires railways to transport manure, Mysore wants an act to facilitate the employment of a large amount of permanent labor.

52. In conclusion of this portion of the subject I quote some interesting remarks in reply to a query as to the weight per bushel, which suggest further investigation in the same direction.

"The weight per bushel varies on the different estates and even on the same estate varies each year, one year heavier one year lighter, caused I think according to the severity of the yellow leaf disease, not so much at the time of the attack, but the year following—but of this latter statement I won't speak of very positively—as I have not sufficient instances to quote. In the picking season of 1875 I had on my estate very bad yellow leaf disease, the weight of my coffee of bushels per cwt. was 4·37, whereas in 1876 it was 4·99. This instance I have noticed as the evil effects of leaf disease. Here is a list of the weights of bushels per cwt. of the different estates under analysis from 1873—1876.

* The silicates would probably contain lime, soda or potash or both, and magnesia.

	1873.	1874.	1875.	1876.	1877.	1878.
C. bushels per cwt	4·25	4·48	4·41	4·61	...	...
A " "	4·24	4·78	4·37	4·99	4·51	4·82
B " "	...	...	...	4·52	...	...
S " "	4·27	4·43	4·19	4·55	...	...

You will see that age does not seem to affect the weight in any regular gradation,* though there may be a tendency to go down. Yellow leaf disease more than the want of manuring seems the fault. The "C" estate had been begun since 1857 and had been worked in a most careless way; yet in 1873 its weight of coffee compares pretty tolerably well. Again the "A" estate was fifteen years old about 1873, at least the part from which the crop came, and had been all this time under native management, yet the weights are not very unfavorable."

53. Question.—What manures are commonly used and what is their effect?

The answers I have received to this question are, from the want of accurate experiment, so indefinite, that I purpose, instead of quoting each in detail, to accede to a widely expressed wish and discuss the subject of manuring generally. In a lecture, I had the honor to deliver at Mercara to a large assembly of Coorg planters, I occupied a considerable portion of the time at my disposal with this subject, but as other than the planters then present will probably peruse this report, I intend to recapitulate what I said on that occasion, and enter with somewhat greater minuteness into some parts of the subject that have hitherto been somewhat overlooked. When does a soil require the addition of manure to make it more productive, is a question to which no single answer will suffice. It may be that a soil is naturally poor in some of those ingredients essential to plants. Such an one can have its deficiencies gauged by chemical analysis which will point out whether the addition of a single plant food is sufficient, or whether a more general manure containing several is required. Or again one soil may contain an ample amount of every kind of nourishment a plant requires, yet they may be unavailable, that is existing in such a form that the plant is unable to assimilate them. Here, a chemical analysis, such as is usually quoted, which is but partial, is apt to be misleading to many, for though it will shew probably every constituent present, it does not shew which are soluble or might readily become so when in contact with rain water and the acids it meets within its passage through the soil. It is to a soil of this class that a manure, such as lime, acting on the constituents already in the soil, as well as serving where necessary as plant foods, often shews such a marked effect. And it must not for a moment be supposed that dormant constituents in soils are useless. They ensure a continuation of fertility in future years, nature providing the means to gradually bring them into a more and more decomposable condition, so that year by year minute quantities reach a state of solubility that can be taken advantage of by the growing plant. Several manures and the action of the air and rain which, as I have shewn, act with so much greater an effect, when the soil is thoroughly loosened by cultivation, add greatly to accelerate the force of natural decomposition, and the analyses I have quoted on a former page shew with what avidity a plant avails itself of the constituents placed within its reach, even absorbing under a condition of plethora an excess of its normal requirements. Perfect cultivation is the thorough utilization of what nature places at the disposal of the husbandman combined with what he, by using means to assist nature, can render assimilable for the plants he cultivates. The greater the amount of plant food ready for the growing plant, the larger may the yield from that plant be expected to prove. But, in increasing the decomposition of the inert constituents of the soil, rendering them food for plants and so increasing the luxuriant growth of a crop that is in quantity removed from the spot and disposed of for the benefit of the cultivator, conditions arise that are not met with in nature. Some constituents of rocks have a greater degree of solubility than others, and the proportion of each varies. It often happens that of the foods required by plants, those which they absorb in the greatest quantity are those present in but small proportion in the soil. This will be seen by comparing the analyses of coffee bean and the soils of coffee estates already given. Potash, phosphoric acid, lime and magnesia are the inorganic constituents present in the largest quantity in the bean, and usually in the smallest amount in the soil. Now if the plant assimilates any one of these from the soil faster than the combined action of natural agencies quickened by man's assistance can render it available, a period must arrive when of the constituents most largely absorbed that present in the least quantity sinks below the wants of the plant. If there be no dormant unavailable supply in the soil, the plant will carry on but a languishing existence unable fully to utilize the other foods at its disposal, and

* NOTE.—The effect of season will mask a tendency to a gradual change by exhaustion if there be one.

sterility will ensue when the last atom is absorbed. But if, as is usually the case, only the active combinations are temporarily exhausted, then a check will be caused until nature, gradually acting on the dormant constituents, places a further demand at the disposal of the plant. By adding the constituent or constituents wanted in an available form in manure, and by calling in increased natural action by the exposure to atmospheric agencies incident on cultivation, this period is reduced to a minimum. Such in a few words is the well-proved theory of the exhaustion of the soil.

54. Manures used for its restoration may for simplicity be divided into general, or those containing most or all the foods a plant requires, and special, or those containing but one or two. Of the former cattle manure and composts are the chief, and as I saw both good and bad methods of making both during my tour, I will briefly discuss the former. As the method of housing stock for the purpose of making manure greatly affects its quality, I may commence by mentioning two methods either of which can easily be adopted where the rain-fall is not excessive. The first of these is that known to farmers as the "loose box system" which provides a shallow level sunken pit, say 2½ feet deep, placed beneath a water-proof roof. This is for the reception of the droppings of the cattle and the litter strewn about for the purpose of cleanliness and adding to the bulk of the manure. The pit is separated into divisions by posts and rails so as to form a single or double row of stalls, so that each beast can have a separate stall of some 8 feet square; but on estates where cattle are numerous and of the small size usually met with in India, several might occupy a somewhat larger stall. It is advisable to have numerous stalls or divisions, first to secure to each animal room to get at its food, and secondly to cause a uniform dropping of excreta by preventing the beasts crowding together at one end. The food, whether grain, oil cake or fodder, should be given in long troughs so that each animal can secure its share, and it is well to have these troughs movable so as to rise as the manure rises. A lump of rock salt in each will be much relished by stock and assist them in keeping in health. The manure as it falls must not be disturbed, but covered daily with a sufficient supply of litter to completely absorb the urine, and to keep the animals from becoming soiled when they lie down. If the land to which the manure is to be applied be of a heavy loamy or clayey character, more litter should be given than if the manure be required for an estate with a light soil, and at all times a sufficient supply should be afforded to absorb the whole of the urine, none being allowed to trickle away. Excess of moisture can be avoided and shelter given to the cattle by having the eaves of the roof built to overhang a foot or so, at the same time allowing plenty of height to the supports to give a good cubical content of air. The sides may be open, except that most exposed to the rain, which, in the monsoon season, can be secured from drifting in by temporary contrivances such as a mud wall, mats or thatch. In avoiding the formation of too wet manure which would be injurious to the hoofs of the cattle and cause a heavy loss by the draining away of a darkly colored stream rich in humate and ulmate of ammonia, the other extreme of permitting it to become too dry must not be forgotten. When manure has been disturbed, any appearance of mildew indicates that decomposition has at one time been too rapid and at too high a temperature, causing a disengagement of the readily volatile carbonate of ammonia. If on moving manure the smell of this pungent salt be noticed, it shews that its liberation is still going on, and steps should at once be taken to arrest further loss by lowering the temperature. Indeed with the high thermometer met with in coffee-growing districts to retard decomposition and keep down the temperature requires much care, but the value of properly-prepared manure amply compensates for any trouble that may be taken in its manufacture.

55. The curious and I should suppose unique practice of the ryots in two or three taluks in the west of Mysore of heaping their cattle dung in the open field and repeatedly exposing it to dry so as to reduce it to powder, presents no feature to commend itself to the planter. I presume practice has proved to the Gauda that where the rain-fall is excessive for the growth of dry land crops and the land on the surface partially exhausted, ammoniacal manures cause the crops to run too much to straw, but such reasoning is not applicable to coffee. If this native manufactured-manure can be purchased at a very low rate, it may, under favorable conditions for transport, be worth the expense of carting, but a far better product for application to coffee will be obtained, if the planter grazes his own cattle and adopts means to secure all the constituents of their manure.

56. A second method of housing cattle and affording facilities for keeping pigs in addition, which is employed on an estate in Coorg and worthy of more general use, is as follows :—

A central pit of any length, 9 feet deep and 16 feet wide, has on either side level with the top two cattle sheds each 16 feet wide, 6½ feet high, the whole being covered with corrugated iron roofing thoroughly water-tight. The cattle are kept on earthern floors, and their droppings are lifted daily and

thrown into the pit, together with a small scraping from the floors, which when requiring it are re-laid with fresh soil. The pigs are kept below in the centre pit, which contains the cattle droppings. The bulk of manure is increased by rushes, ferns and jungle stuff, and once a week a layer of crushed bones is added and any cattle or pigs that die find a grave in the heap if there be a sufficient depth of material to cover them. The cattle are fed by grazing, and the pigs are kept in the pit, except once a week, when they are let loose to wallow in an adjacent swamp. In erecting such a building it is well to remember that labor in emptying the pit may be much lessened if the building be placed lengthways on a hill side, so that carts may readily be backed in from a road at either end level with the bottom of the pit. The earth that has to be excavated to form the pit, will, if thrown to the lower side of the hill, raise the ground so that both cattle standing places may be level. I believe an improvement might be made, and the labor of throwing the cattle droppings down into the pit saved, if the pit were to have its sides sloped away to touch the outer walls, so that the manure might fall through a sparred floor, and find its level by slipping down the inclined planes. Supports for the inner ends of the two floors would require to be either strong pillars or brick arches built lengthways.

The following are one or two of the more conclusive replies I have received of the value of an application of cattle manure mixed with bone, &c.

Coorg.

57. From an estate with open soil abounding in stones and receiving a heavy rain-fall.

"In answering this question, I had better give you the history of my experience. In the monsoon of 1875 which was heavy, my thirty acre field had a most virulent attack, the crop on it was very light so that could not have been the cause. The leaves all dropped off and then what little crop there was. It then attacked the wood which died back, in fact I thought at one time the whole field was dying. I was unable to do anything on account of the heavy rain, but in October when the rains broke I applied a mixture of crushed bones, ashes and cowdung. This had been mixed some years and kept covered up in a pit. The immediate effect of this was to produce a vigorous growth of young wood without a sign of leaf disease. In order to follow it up, the following March I again manured it with a mixture of lime, pulp and dead leaves, and in the monsoon of 1876 there was only a slight attack of leaf disease. I again in March 1877 manured with Pearse's patent Coffee Manure. In the monsoon of 1877 it was free from leaf disease, and in 1878 it had no manure and no leaf disease, but it gave a crop of 7 cwt. an acre all over, in consequence of which leaf disease is now to a certain extent shewing up."

Mysore.

"Whatever small amount of manure has been used, has been cattle manure of a very poor nature. However I have remarked this year that the trees so manured have been freer from the attack of leaf disease than those which had no manure applied to them."

"Composted manure composed of a little of every thing and a great deal of cattle manure is the principal application used on this estate, and the effect simply is to increase vigor and add greatly both to appearance and yield and lessen generally the tendency or susceptibility to disease. The only drawback in regard to such manure is the difficulty of getting a sufficient quantity of it. A planter should have at least four acres of grazing land for every acre under cultivation, but Government object to the granting of such lands on terms compatible with the planter's means. All manures by adding to the general vigor of the plant greatly tend to mitigate the effects of leaf disease, but those that have decidedly a *mechanical* effect on the soil in keeping it loose, sweet and active are decidedly the best."

58. Presuming the manure to be made in a satisfactory manner and with a view to suit the particular wants of the estate, the next point is to take care that as small an amount as possible of volatile and soluble matters are lost before it is applied to the plant. If it be determined to empty out the sheds and store the manure near to where it will eventually be required, one or two small matters require consideration. The exposure incident on moving manure hastens decomposition, and if the manure be not required for some months, its too rapid decay may be checked when forming a heap by running the loaded carts over the manure as it is deposited on the ground, then backing the cart and emptying it against the heap. This method will consolidate the heap and by preventing the admission of air, retard oxidation. If, on the other hand, the manure be insufficiently rotted when removed from its place of manufacture, the carts containing it can simply be backed against the heap in process of formation, thus

avoiding pressure and leaving the heap in such a light condition that decomposition can go on with rapidity. I noticed on several estates manure carted out and left exposed to the atmosphere on the roadways in a most unworkman-like manner. Although it may be intended to convey the manure to the trees the next day or at furthest within the next few days, a layer of earth should always be thrown over the heap. A very thin covering is sufficient to absorb volatile matters and prevent a passing shower washing away the soluble salts, and the expense of this operation need not be large, if, instead of a number of small heaps, a number of somewhat larger ones be made. A glance at the composition of well rotted dung will shew what a serious loss may be incurred by careless exposure, the whole of the soluble organic and inorganic matters being liable to be dissipated at once, while a considerable proportion of the insoluble inorganic matters would be lost on long exposure.

59. Composition of Farm yard manure.*

	No I.		No. II.	
	Fresh cow and pig-manure.		Well rotted.	
Water		66·17		75·42
Soluble organic matters 1		2·48		3·71
Soluble organic matters				
Silica	·237		·254	
Phosphate of lime	·299		·382	
Lime	·066		·117	
Magnesia	·011		·047	
Potash	·573		·446	
Soda	·051		·023	
Chloride of sodium	·030		·037	
Sulphuric acid	·055		·058	
Carbonic acid and loss	·218		·106	
		1·54		1·47
Insoluble organic matters 2		25·76		12·82
Soluble silica	·967		1·424	
Insoluble silica	·561		1·010	
Oxide of Iron, alumina and phosphates	·596		·947	
Containing phosphoric acid	(0·178)		(0·274)	
Lime	1·120		1·667	
Magnesia	·143		·091	
Potash	·099		·045	
Soda	·019		·038	
Sulphuric acid	·061		·063	
Carbonic acid and loss	·484		1·295	
		40·5		6·58
		00·00		100·00
1 Containing nitrogen	·149			·297
Equal to ammonia	·181			·360
2 Containing nitrogen	·494			·309
Equal to ammonia	·599			·375

60. I may here remark that the composition of the manure naturally varies with the nature of the food supplied to the animals producing it, and also with the kind of animal and its age, as well as the

* Wrighton's Agricultural Text Book.

amount of exposure to which the manure is subjected during the process of manufacture. Another variable item is the kind and amount of litter supplied as bedding.

61. If the manure heaps are to be left intact for any time, several inches of earth may be placed over them, or if thatching material be at hand, a rough thatching will not be thrown away. A drain should also be cut round the heap so that no flowing surface water can soak in, and their shape should be such that a heavy rain will not saturate the mass by gravitation. With regard to the actual application of farm yard or cattle box manure to the tree, several methods may be noticed. If the land has not been disturbed for some time, it may be spread on the surface and dug in, thus disseminating it through the mass of the soil, which will then derive the fullest benefit from its mechanical as well as chemical action. If it be thoroughly decomposed, and a rapid action is desired, it may be placed in pits and diluted with earth, a little quick-lime added, and earth at *once* placed on the top. This will cause ammonia to be disengaged and absorbed by the surrounding soil, but no time must be lost in covering over the lime and manure, or the former will be the means of causing irreparable injury in dissipating the ammonia into the atmosphere instead of the soil. Fresh cattle manure containing a large bulk of straw and vegetable matter and little dung, can, under similar conditions to those quoted in a former page of this report, be left on the surface of the soil, but only under *very* exceptional circumstances is such a course commendable.

62. A manure produced on coffee estates in considerable quantity, that must be mentioned in this report, is human excreta. It is reported by Dr. Voelcker that, taking an average of all ages of a European population, the following amounts of excreta is obtained per unit per annum :—

23 lbs of dry matter contained in the solid excreta.
34 lbs of dry matter contained in the liquid excreta.

Or for simplicity sake we may assume that each person of a population produces in the solid and liquid excreta 56 lbs of dry matter per annum, which yields in round numbers 10lbs of ammonia and $5\frac{1}{2}$ of phosphates. But as Mr. Robertson points out in an article on* "some manurial substances yet unutilized."

"In India as the food of the people is bulky and innutritious consisting chiefly of grain, animal food forming but an inconsiderable item, we may, I think, estimate that in this country the dry substance in the mixed excreta of man, will weigh per head of the population about 45 lbs capable of yielding on decomposition, say 6lbs of ammonia and 3 lbs of phosphates. With these figures the value is as follows :—

	Rs.	A.	P.
6 lbs of ammonia at 6 annas per lb	2	4	0
3 lbs of phosphates at 1 anna per lb	0	3	0
Other matters	0	1	6

The total value of excreta per head per annum.....2 8 6"

As in this amount $\frac{5}{6}$ths of the ammonia and $\frac{3}{4}$ths of the phosphates is contained in the urine which cannot be readily collected on a coffee estate, only As. 8, P. 3 is left to be accounted for as the value of the solid excreta per head. Under these circumstances it seems to me injudicious to lay too much stress on interfering with the habits of coolies except where absolutely necessary, and where objections to their defective habits of sanitation cannot be met by constructing their lines in such a manner that they can readily be annually or biennially moved on to a new part of the estate. There are at the same time many different methods by which the deodorization of solid excreta can be effected. A simple covering by earth, ashes, charcoal, gypsum, caustic lime (applied to fresh excreta only), and dry clay, will each and all prove effectual either used separately or combined. A good method is to dig trenches, which the coolies must be induced to use and have a layer of some deodorizer placed in daily until the trench is full, when a new one may be commenced. The contents of the first made trench can be utilized in a few months, as all sign of the original composition of the mixture will be found to have disappeared.

* Annual Report of the Superintendent, Government Farms, (Madras Presidency) for the year ending 31st March 1877.

63. *Coffee pulp.*—This is another manure met with on a coffee estate on which a too high value as a manurial substance is, I think, frequently placed. I regret I am unable to quote an analysis of this, but an idea of its value may be obtained by the subjoined analyses of other somewhat similar fruits :—

	Peach.	Cherry.	Plum.
Water	85·0	80·4	85·2
Albuminoids	·5	·8	·4
Sugar	1·8	8·7	2·3
Free acid	·7	1·2	1·3
Pectose and gum	8·0	·8	·4
Cellulose	3·4	·8	1·0
Mineral matter (omitting stones)	·6	·56	·55

64. It will be noted that mineral matters are present in an exceedingly small proportion, the bulk of the fruit consisting of water and carbohydrates. Pulp will be most usefully employed to aid decomposition by the heat and carbonic acid it evolves on its own decay ; consequently it is best mixed while moist with a compost containing lime which will sweeten it, while the gases it evolves may be employed to break up other materials in the compost such as bones or oil-cake. In any mixtures of this kind plenty of moisture is essential, and earth should be present both as a constituent of the compost and a covering material to the whole.

65. *Wood ashes.*—Throughout this report I have laid so much stress on the value of humus in influencing the mechanical condition of the land, that in mentioning ashes as a manure it is only in the hope that they are procured off the estates, as rotting and fermenting rather than burning should be the method of utilizing all debris. Ashes vary much in value according to the source from which they are derived. Those of young growth are more valuable than those the result of burning old timber. Thus in an analysis of twenty species of the leaves of trees the average percentage of ash they contained amounted to a little over three per cent. The analysis of some twenty varieties of bark, the average amount of ash was two and a half per cent ; while in thirty varieties of wood the ash only amounted to an average of one half per cent. As ashes are necessarily often mixed with a considerable amount of earth, their value per bushel is greater the less the weight. Probably pure jungle ashes will not exceed twenty or twenty-two pounds per bushel. The presence of charcoal, though lessening the chemical value of the manure, is at the same time valuable as a mechanical absorber of gases of great power. As a source of ashes I may mention the "*Lantana*" now run wild over so much of the coffee districts of Coorg. It is a rapid grower and a surface feeder, and in consequence is probably rich in valuable mineral matters. If it were used it might be first employed to burn clay at a low temperature and thus add another source of manure to the planter. The following is an analysis of a good sample of Ceylon jungle ashes by Mr. Hughes taken from the "Ceylon Observer."

Water	7·89
Organic carbonaceous matter and combined water	13·17
Oxide of iron and alumina	16·70
Carbonate of lime	30·80
Sulphate of lime	3·19
Phosphoric acid	trace.
Carbonate of potash	21·46
Carbonate of soda	1·06

The analyses of a sample of Coorg jungle ashes I have already given.

66. *Oil cakes.*—A considerable number of oil cakes are available for the Indian planter, but I regret I am only able to furnish a meagre list of analyses for comparison. The following are procurable in one or other of the coffee districts as manures though the first three of these are also admirable cattle foods if pure:—

Yellu or gingelly.	Sesamum orientale.
Hutchellu.	Guizotea oleifera.

Ground, earth or pea-nut.	Arachis hypogæa.
Ippe.	Bassia longifolia.
Honge.	,, latifolia.
Castor-oil.	Racinis communis.
Mustard.	Sinapis nigra.
Cotton.	Gossipium.
Pinne koi.	Calophyllum Inophyllum.
Neem.	Azadirachta indica.
Cocoanut.	Cocos nucifera.

The following are the analyses of some of these:—

	Undecorticated Cotton Cake.	Yellu or Gingelly.	Castor-oil seed Cake.	Ground nut Cake.	Cocoanut Cake.	Bassia Cake.
Moisture	11·5	11·5	9·95	9·8	12·7	13·54
Organic matter	82·2	76·5	81·07*	83·1	82·2	80·79*
Ash	6·3	11·8	8·98	7·1	5·1	5·67
*Contains Nitrogen... ...	...	...	8·69	...	...	2·73
Ash consists of—						
Phosphates	1·71	...	4·59	...	...	1·43
Alkaline salts	1·77	...	1·80	...	...	3·63
Sand	·55	...	2·69	...	...	·61

67. The chief value of oil cakes for manure lies in the amount of nitrogen present in the organic matter, and to a less extent in the phosphates and alkaline salts in the ashes.

The analysis of castor-oil seed cake given above shews that it is very rich in nitrogen, consequently of a forcing character as a manure tending to develop leaves and shoots. Its action in this respect is however not so rapid as that of nitre which I have to notice later on, as it does not decay quickly, and in consequence cannot at once yield up its valuable constituents. Conversely the duration of its action would extend over a longer period.

The analysis of the Bassia cake shews it to be of much poorer composition, but the large amount of water given in this particular sample lowers the proportion of the other constituents. On the Bangalore Experimental Farm I have ascertained that while castor-oil cake gave the best results weight for weight on rich land that could stand forcing with nitrogenous manures, the Bassia or honge cake proved itself far superior to castor-oil cake on poor sandy land in growing a crop of sugar-cane. The considerable percentage of alkaline salts in this manure together with the small amount of Phosphates it contains points to the advisability of using it mixed with bones.

68. Oil cakes if applied by themselves should be broken up as small as possible, but it is more judicious to use them in a compost with bones, pulp, and if possible cattle manure, applying the mixture after the oil cake has become thoroughly decomposed. In fact in the vast majority of cases a mixed manure rather than one containing only one or two plant constituents will give the best result.

69. *Fish manure.*—This is a manure of very uncertain composition from the great temptations that exist to adulterate it largely with sand. I regret that I can give no reliable analysis. The following is the composition of fish and sea-weed respectively:—

	Fish.		Sea-weed.	
	Mackerel.	Sprats.		
Water	68·7	64·60	Water	18·8
Nitrogenous matter	13·5	*15·90	Albuminoids	9·4
Oil	12·5	19·50	Mucilage.	55·4
Common salt	2·2	...	Cellulose	2·2
Mineral matter	3·1	†2·12	Mineral matter	14·2

* Containing Nitrogen	... ...	11·75	per cent.
† Containing	Phosphoric acid.....	43·52	do
	Lime	23·57	do
	Potash... ...	17·23	do

Besides these matters there would in some samples be considerable amount of phosphates if fish bones abounded, and little if shells and coral were present. Salt is also present.

70. Fish manure will act as a forcing manure for foliage best when it contains much dried fish, and as a phosphotic manure when fish bones predominate. The water in the fish will be to a great extent dissipated in drying, but even when as dry as possible the manure will be always liable to increase in weight in damp weather through the absorption of water from the atmosphere by the hygroscopic salts it contains.

71. The next manure to discuss is lime, a manure which, in conjunction with sulphur, has recently been prominently brought into notice in Ceylon as a special cure for leaf disease. As a direct food for plants it is I believe generally found in sufficient quantity in coffee soils in Coorg and Mysore, though an analysis of a coffee plant ash shews that it enters largely into the composition of the ash of the whole plant, and that its presence must not be overlooked. The following analysis of an entire coffee plant is taken from Dr. Shortt's "Hand Book of Coffee planting in Southern India," in which it is stated the plant was 10 years old, 15 feet high and grown under the shade of a mango tree, consequently it can hardly be considered an average tree, but as I have no better analysis to insert, this one finds a place.

72. Composition of a coffee plant ash in 100 parts :—

Potash	15·76
Soda	18·98
Lime	26·07
Magnesia	4·26
Ferric oxide	9·22
Phosphoric acid..	13·28
Sulphuric acid	2·79
Sodic chloride	8·35
Silica	1·29

The ash formed 5·55 per cent of the entire plant.

73. As a soil alterative, and a burning agent to destroy parasitic spores and sour organic compounds caustic lime or lime freshly slaked is of the utmost value. In a previous section I have recommended digging in vegetable debris over the entire surface in opposition to the old plan of placing it in pits, giving as a reason that under the former plan oxidation is rapid and continuous, while in pits decay is slow. If in the debris a number of diseased leaves exist and there be a probability that the soil is full of the spores of the '*Hemilea*,' I would recommend that immediately before the digging commences a dressing of freshly slaked lime be scattered over the surface and lightly dug in. I would advocate the use of unslaked lime were it not that it is difficult on an estate to reduce it readily to powder, while in lumps its employment would be too partial in action and be likely to injure the roots of the coffee tree. In any place however where the disease is exceedingly severe and the plants so seriously checked that the production of a next year's crop cannot be relied on, a dressing of unslaked lime cautiously applied might be advisable though from its caustic nature the utmost care would have to be exercised.

74. Though I do not believe a lime treatment will at once and entirely rid the estate of the pest, I am of opinion that it will effectually destroy all the spores with which it comes in contact, besides sweetening the ground and increasing the amount of available plant food, thus aiding the more vigorous growth of the plant and giving it a sufficiency of vitality to render attacks of the fungus in the immediate future innocuous. If facts were in existence to prove that the duration of the life of the spores in the ground was limited to a season, and that unless renewed stores were added by the falling leaves the pest would die out, an attack either on the leaves before they fall from the tree by gaseous applications, or when they drop to the ground by collecting them in pits and then burning them, either by fire or lime, might be advisable. But with the present state of our knowledge such methods do not commend themselves to me as likely to be effectual, nor have they stood the test of experiment, and I feel confident we must rely more on securing a healthy soil and a healthy plant on which the enemy's attacks will prove futile, than in carrying on a war of extermination.

75. Quicklime undergoes two changes on exposure. It absorbs water and becomes hydrate of lime or slaked lime, and if exposed to the air for a length of time gradually draws in carbonic anhydride by which it

re-assumes the form of carbonate of lime. The same action takes place in the soil by the decomposition of organic matter and the absorption by the lime of the carbonic acid. The sourness of land caused by the presence of an organic acid is removed by the addition of lime, which combines with the acid to form a harmless product, while it decomposes such injurious salts as humate of iron, probably present in undue proportion on many estates in Mysore overlying or in close proximity to laterite. Lime is also a valuable addition to land by its action on inorganic matters, causing a gradual decomposition of silicates of alumina the basis of clay. Caustic lime favors the production of a double silicate of alumina and lime, which is a great advance towards further decomposition, as under favorable conditions the lime is again ousted from its combination by soda and potash, and these by ammonia, each action producing a more readily soluble compound than the one preceding it.

76. Caustic lime also performs an important action in the soil and in compost heaps in forming nitre. As I have already mentioned, lime added to stale manure in pits is a hazardous operation entailing the rapid evolution of ammonia. But the action of caustic lime, or with a lessened intensity freshly slaked lime, on undecomposed manure mixed with earth, is different. In fresh manure the nitrogen, instead of being present as ammonia, exists in its simple form, and if lime be added to this a non-volatile product nitric acid is formed. This is willing to unite either with lime or potash, the latter for preference, forming in the one case nitrate of lime, and in the other nitrate of potash or nitre. The difference in effect between applying lime to stale manure and to a freshly made compost is important, or the friend may easily become the enemy. Lime if applied to the soil alone should not be deeply buried as it has a habit of sinking and as a destroyer of fungus several light dressings would probably be more effective than a single heavy one. Its action on the soil has been found to become less and less marked each time it is applied. If it be contemplated to apply both manure and lime to land for the purpose of checking apparent leaf disease, the lime should precede the manure. But if lime be added as a preventive agent, it is better combined with other manures in the form of compost as it will increase their action. The full effect of a dressing of lime is not obtained on undrained land and is more marked on the second year after its application than the first.

77. The next class of manures to be noticed are those in which phosphoric acid is the chief ingredient. The substances available for its supply are apatite, coprolite, guano of several kinds, superphosphates, and bones in their natural state, steamed and burnt, and other less important substances. To the Indian planter bones in their various forms are of the chief interest as they are a local product easily obtainable in most districts. The following analyses of the bones of various animals yielding the chief supply may be of interest:—

		Man.	Sheep.	Goat.	Bull.	Horse.
Inorganic matters.	Phosphate of lime	59·63	55·94	47·07	54·07	54·37
	Carbonate of lime	7·33	12·18	9·09	12·71	12·00
	Phosphate of magnesia	1·32	·1·00	1·59	1·42	1·83
	Other salts (unimportant)	·69	·50	1·02	·80	trace
Organic matters.	Cartilage	29·70	29·68	39·58	29·09	27·99
	Fat	1·33	·70	1·65	1·91	3·11

Thus bones vary in quality according to the species of animal that yields them, and also according to the age of the individual. Thus in the bones of young animals there is more gelatine and less earthy matter, while the latter is richer in phosphate of lime than when the animal becomes mature.

78. To supply phosphoric acid equal to 100 lbs. of phosphate of lime requires of—

	lbs.
Bone ash or animal charcoal about	145
Boiled bones	200
A good superphosphate	330

Of bone meal, bone dust and crushed bones a variable amount, depending on the age and species of the animal yielding the raw material. Bones that have been steamed or boiled contain about one quarter of their weight of organic matter which is readily decomposed by contact with the air and moisture in the soil. As the bone does not decrease in bulk by boiling, it is left in a highly porous condition, while the very solution and decomposition of the organic matter is a source of carbonic acid within the bone itself, aiding the carbonic acid contained in the rain water in the soil to render the phosphates in the bone soluble.

79. Burnt bones are less valuable than unburnt bones, notwithstanding the larger amount of phosphates they contain; because they have lost their nitrogenous organic matter, and secondly because the high temperature to which they have been subject has caused the phoshpate of lime to assume a less soluble condition, both causes acting in retarding a rapid decomposition in the soil.

80. The value of a phosphatic manure depends on three points. The nature of the combination in which the phosphoric acid occurs, of which I shall have more to say when discussing superphosphates, secondly on the degree of solubility of the phosphates, and thirdly their amount. The physical condition is also of high importance. Thus a fresh bone before it is broken has but a small surface on which action can take place, and the presence of fat and gelatine greatly retard decomposition. By boiling or burning these materials are got rid of, but at the expense of the nitrogen in the gelatine. The physical conditions are however improved by boiling in that the bone is rendered porous, and has organic matter left in its substance to yield carbonic acid on decay. To still further lay a bone open to decomposition, it should, after boiling or burning, be crushed, and the more it approaches a powdery condition and affords an extended area on which action can take place, the greater will be its value. But it is not sufficient that bones are reduced to powder, unless this be properly applied. It is an injudicious, though common custom, to put crushed bone by the handful in a hole near the stem of the tree. The value of the sub-division of the bone is thus in a great measure lost, as only a very limited number of feeding roots of a plant can avail themselves of the supply. Indeed the system of placing manures in holes dug close to the tree and small in size, and leaving the manure in a concentrated state is in several ways to be deprecated. In the first place the feeding roots are not under natural conditions seeking their nourishment close to the stem, but ramifying far and wide in search of nutriment. So little is this fact noticed that I was on one occasion told by a planter with great complacency, " I put the bones close to the stem and as much out of the reach of the rain as possible, and I'm proud to say sir, I don't believe they have been thoroughly wetted yet". Healthy decomposition and the dispersion of plant food in solution is thus retarded, because only a portion of the falling rain finds its way through the pit, whereas, if distributed evenly through the soil, the manure is more readily brought in contact with its decomposing action. Again some substances which in small amounts are beneficial, such as salt, if too concentrated act injuriously, and cause roots to turn away instead of towards them. The more a manure can be distributed through the soil, the better, and though on steep slopes it is difficult to manure in any other manner than by pits, let them be as large as possible, and let the manure when placed in them be thoroughly mixed with earth, and not left in a mass; and wherever the lay of the ground permits, substitute the practice of digging it in evenly all over the surface. It should not be a matter for satisfaction when disturbing ground near a coffee bush to find traces of the former manuring in undecomposed bones or oil cake, such a sight simply means that so much of the capital sunk has not been utilized by the plant and consequently it has in all probability produced a lesser crop than it would have borne, had the manure been applied more judiciously. As bones yield up their phosphates tartly, the effect of a dressing lasts for some time, especially if bones not reduced to powder be employed. The effect of bones is not so visible in a darker tinted foliage as some manures, nor is it to be expected. Their effect is rather to increase the weight of the crop by affording to the plant the phosphoric acid necessary as a constituent in the ash. If trees be planted 6' × 6', that is, 1,200 to the acre, and half a pound per tree were given as recommended by some authorities, this would amount in weight to something over 5½ cwt, per acre. Such a quantity is I think excessive. Probably a third to half this amount applied in a compost every third year would with good cultivation be sufficient, but extended experiments with varying amounts would give on each estate an exact answer for that particular locality. As phosphates decompose slowly, it is well to apply the more inert forms, such as, roughly crushed bones at an early period on young estates, for there is no danger, if the land be fairly drained, of their being lost, and it is better for a plant to have the manure at hand in the soil in plenty than to permit it first to

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produce a crop and then return an equivalent for the amount it takes away. Besides, though found eventually in the ash of the beam, phosphates are required in considerable amount in young growth passing through the entire circulation of the plant. Thus the ash of the young leaves of many plants and also the twigs contain a considerably larger amount of phosphates in proportion to the total quantity of ash present than is found in mature leaves and other old parts of the plant.

Thus :—

	Phosphoric anhydride in ash.
Walnut leaves, Spring	4·9
Autumn	1·1
Beech trunk	·3
„ branches	1·0
„ brushwood	1·5

81. Besides the form of bone manures I have already mentioned, there remains a method of using bones so that every portion of the bone may be quickly utilized, and the valuable nitrogenous matter lost in purchasing boiled or steamed bones or bone ash kept on the estate. This is by the "fermentation" process. Bones may be fermented either in moist compost or manure heaps, or by mixing with fresh pulp. If the manure be not required for some time, the bones will not require breaking, but if it is to be used at an early date then a rough crushing will facilitate decay. Lime may also be added with advantage in the form of quicklime. The exact method of manufacture will vary on each estate, but in some form of compost it appears to me pulp can be best utilized to assist the decay of bone, and with lime and earth form a valuable mixed manure.

82. A last form of phosphates I have to mention is superphosphates. I do not believe there is any occasion for their introduction on Indian coffee estates, as an equally good acting manure may be made from local materials, especially by adopting the "fermentation" process to which I have alluded ; still as they are of interest to several Coorg planters who employ them, I will as briefly as possible explain their composition. Phosphate of lime exist in three forms. In each of these a fixed amount of phosphoric acid unites ; with three equivalents of lime to form—tri-calcic phosphate,—with two equivalents of lime and one of water to form bi-calcic phosphate,—and with one equivalent of lime and two of water to form mono-calcic phosphate.

The phosphate of lime in bones is the tri-calcic phosphate which is insoluble until brought into contact with the carbonic acid and water in the soil, when it is *slowly* changed into bi-calcic phosphate, and carbonate of lime. In manufacturing superphosphate this slow action is changed into a quick one by substituting the stronger sulphuric acid for the weaker carbonic acid, and the products of the decomposition of the tri-calcic phosphate instead of being bi-calcic phosphate and carbonate of lime, are mono-calcic phosphate and sulphate of lime. The mono-calcic phosphate instead of being slowly soluble in rain water is readily soluble, but although this process of manufacture produces a salt that can be more quickly availed of by the plant, it is found in practice that it is too acid to be taken up, until meeting with the lime present in the soil it is changed back again into bi-calcic phosphate. The application of a superphosphate consequently becomes from its expense a risky proceeding on the part of the planter who suffers from a deficiency of lime in his soil, and also a heavy rain-fall, by which the readily soluble mono-calcic phosphate might be washed away before it had time to combine with lime and serve as food for plants.

83. By keeping a newly made superphosphate for some time a portion of mono-calcic phosphate to the extent of two or three per cent sometimes falls back into bi-calcic phosphate, and this change by the ordinary method of conducting an analysis is not shewn ; consequently if purchased by a planter who buys on analysis this may be a source of disagreement, his analysis of the old product not agreeing with that of the manufacturers taken at the time of manufacture. In reality, however, the "reduced phosphates" are more valuable than "soluble phosphates," as they are ready for instant assimilation by plants and cannot so readily be washed out of the soil. As superphosphates are very liable to adulteration they should be purchased only from well known manufacturers, or on arrival a sample should be at once submitted to an analytical chemist for analysis and report. To shew the analyses of bad and good superphosphates, I extract the following from Professor Wrightson's Agricultural Text-book.

84. Composition of three samples of artificial manures :—

	No. I.	No. II.	No. III.
Moisture	17·46	13·33	10·23
* Water of combination and organic matter	18·82	25·51	22·65
† Mono-calcic phosphate	4·97	6·45	18·91
Insoluble phosphates	7·29	17·60	12·05
Calcium sulphate, alkaline salts and magnesia	35·17	28·96	32·06
Sand	16·29	8·15	4·10
	100·00	100·00	100·00
* Containing nitrogen equal to ammonia	1·07	·83	2·02
† Equivalent to mono-calcic or soluble phosphate	7·79	10·10	29·60

The comparative money value, according to the preceding analysis, is—

	£	s.	d.	
For No. I	4	0	0	per ton.
No. II	4	10	0	,,
No. III	9	5	0	,,

The price at which they were actually sold, delivered, carriage paid, at the nearest station was :—

	£	s.	d.	
For No. I	7	10	0	per ton.
No. II	7	5	0	,,
No. III	8	0	0	,,

85. I may here remark that if on arrival an artificial manure emits a strong smell, it is not an evidence of its value, as small quantities of volatile pungent salts, such as carbonate of ammonia, may readily be introduced for the purpose, while it is an indication that it is daily losing value by a decomposition that produces the pungency. The application of a superphosphate to a soil containing salts of iron in easily decomposable conditions and in large quantity is of doubtful value, as probably the phosphoric acid would unite with the iron and form a most insoluble compound of phosphate of iron, useless to plants.

86. Nitre, nitrate of potash, or saltpetre as the salt is variously named, is an Indian product well worthy the attention of planters. I believe the nearest source of supply to be the Madras Collectorates of Coimbatore and Bellary. Although useful as containing potash, its chief value lies in the nitrogen, as at any rate our coffee soils generally, if not always, contain sufficient potash for the wants of the plant. I only met with a single planter on my tour who used this salt, but he has been in the habit of employing it for many years and with excellent effect. The manure is expensive in the first instance, but probably if inquiries were made of the local authorities, and it was generally known that an absolutely pure salt was not required for manurial purposes, a cheaper supply could be obtained. But against its expense is to be put the small bulk and consequent low cost of carriage, and the exceedingly small amount required per acre. One hundred weight per acre, or at most a hundred weight and a half, is a sufficient dressing, and as it is a substance that may be washed out of the soil by heavy tropical rain it is best distributed broad cast over the estate at the close of the monsoon wherever it is desirable to produce a luxuriant growth of leaf and wood. For equable distribution it should be mixed with twice its weight of sand or dry earth, as it is difficult otherwise to spread it evenly. After a heavy attack of leaf disease probably no manure presents such advantages. Its action is exceedingly rapid, its method of application quick and inexpensive and its carriage easy, though care must be taken to keep it dry. In recommending it thus highly it must be remembered that it is a "Special manure" containing only two plant foods, so that if the land be at all out of heart it should be followed by an application of a more general manure at an early date. On good land well treated it will well repay an occasional application, and to those planters whose estates are in this condition, I would suggest the purchase of a small quantity to test whether a more extensive trial will not repay them. Nitrate of soda is a similar salt that is largely used in England to give luxuriance to unhealthy-looking crops in the spring, but in India as nitre is the indigenous product it will be found the less expensive.

87. Common salt, sodic chloride. This is unfortunately also an expensive manure in India, though for manurial purposes an impure sample will suffice. Indeed salt used for curing fish would, if procurable, be preferable, as it would contain a small proportion of animal matter. The action of salt is to check undue luxuriance, and it is often employed for this purpose in England. It would be valuable on an estate when new leaves and wood appear overstimulated, and generally it is useful to supply plants with sodium. After an application of nitre a dressing of a hundred weight or a hundred weight and a half would be beneficial in forcing strength into the berry by checking undue luxuriance in the foliage. Salt may be applied in the same way as nitre as a top dressing diluted with earth or sand to give it sufficient bulk. Beyond a tradition that it was used by a former planter in Coorg, I found no sign of its employment on coffee estates.

88. Gypsum or hydrated sulphate of lime is a manure existing in the natural state in large quantities in Trichinopoly. As I have no knowledge of its action on coffee, I only mention its presence in South India and suggest its employment in small areas as an experiment.

89. Question.—Is the disease more severe after one or more heavy crops ?

In Coorg.

" More severe." " Undoubtedly it is." " The worst I have seen was on three years old which had given no crop." " The crop does not seem to have anything to do with the disease as for instance trees of seven years old on one estate have the disease after four crops, and the one year old trees on another have it just as bad without any crop."

" Naturally trees weakened by heavy crops suffer more severely than others, but I consider judicious manuring a certain cure."

In Mysore.

" Plants with a heavy crop on them take longer to recover from an attack of the disease, than other plants alongside of them not so heavily laden." " Heavy cropping unaccompanied by judicious manuring doubtless as it enfeebles the tree, renders it more susceptible to the attacks of the disease. At the same time it does not follow that because a tree has borne one or many heavy crops that it will be attacked, or if attacked that it will suffer to any great extent. There are patches of coffee here upwards of 25 years of age, which have never been manured and yet which from their position in hollows shew no signs of being seriously affected by leaf disease." " The disease is always bad during a heavy crop, the " Chicks" in no case bear two running, but I conclude two heavy crops and leaf disease would kill them." " Decidedly worse during and after heavy crops. It is a fact worthy of notice that the disease appears contemporaneously with the formation of the parchment or inner covering of the beam. This parchment becomes very thin after heavy bearing and is considerably influenced and thickened by the application of bones as a manure. I believe this parchment contains a large percentage of phosphate of lime and as it is *entirely removed* from the soil and sent off to the coast, it becomes a question whether this is or not another serious loss to the estate and one which may add its quota towards filling the trees for the attack of *Hemileia.*"

90. I think the last answer of these alone calls for comment. The supposition that the parchment is rich in phosphate of lime is probably correct, reasoning by analogy, as the percentage of phosphoric anhydride in rice husk and grain is about 41 per cent of the total amount of ash of 8 per cent, while it amounts in rice grain without husk to about 53 per cent, but the total ash is only about a half per cent. The thinness of the parchment when bones are required as manure is an interesting practical test that other planters may find useful to confirm.

91. Question.—Has heavy pruning any influence ?

In Coorg.

" None." " I have noticed none." " This estate has been heavily pruned yearly." " Heavy pruning without manure I consider weakens the tree and it therefore is more liable to an attack of leaf disease especially should the showers be late and the tree bleed much, on the other hand heavy pruning with manure will very quickly drive it away."

In Mysore.

"Pruning, in conjunction with digging and weeding, does not render the trees impervious to the disease, and even if manuring is superadded to the above, the trees are still liable to attacks, but the disease then is comparatively harmless." "Heavy pruning weakens the trees and the large succulent shoots resulting from it get the leaf disease very badly. Light pruning freshens the trees and the sap does not seem to be so irregularly distributed, the shoots are therefore more gradually matured and certainly do not suffer so much from any disease." "Heavy pruning, unaccompanied by judicious handling and proper applications of manure, appears to render the young wood less able to resist attacks." "Pruning in a great measure will cure trees with plenty of vitality in them, but there is no greater mistake than heavy pruning; even if it cured the plant, the cure in my opinion would be worse than the disease; heavy pruning means a future growth of nothing but gormandizing wood, and once a plant has taken to that it may as well be dug out, for it will never grow anything else. I could point out a number of estates completely ruined by what is called heavy pruning. It may be managed in two seasons, first season pruning just sufficient to let plenty of light into the tree and to encourage new and healthy wood; second season the trees can be taken in hand and thoroughly pruned into shape as they have the healthy wood caused by the first pruning to check gross growth. I have treated portions of this estate in this manner which are now very nearly free from the leaf disease and have a very heavy crop on them."

"Pruning is beneficial, for the reason that judicious pruning by regulating the amount of crop on the tree allows the tree to have more strength to withstand the ravages of the disease. I have seen trees completely die out from the weakening effects of too heavy a crop and the attack of leaf disease combined." "Heavy pruning decidedly weakens the tree and upsets the equal distribution of sap and leaf disease is an invariable result—or at least—always appears in the most virulent form on trees that have been mutilated and recklessly pruned. Old "shuck" trees which have been cut down, invariably throw up leaf diseased suckers and the same is the case with jungle trees. If a *Bungar Sedlay* tree be cut down all suckers or shoots from the stump are generally found covered with a red fungoid efflorescence closely resembling *Hemileia*."

92. The art of pruning appears from these answers to be so ill-understood by most of the planters whose opinions I quote, that it may be well to discuss the matter somewhat fully. As pruning is essentially an operation to influence the direction of the flow of sap, it will be necessary to consider the causes that promote its flow and influence its nourishing properties. The roots of a plant are the great organs for the imbibition of water and the finer roots and rootlets are often furnished with root hairs to increase their area of absorption, which ceases when their tissue becomes solidified at a later stage of growth. Being pervious to fluids in contact with them, roots contain in their juice similar substances to those in solution in the surrounding soil—water, and if a plant be able to assimilate certain of these in building up its tissues, their abstraction from the soil is compensated for by a further imbibition through the property of osmose. If, on the other hand, the plant has no requirement for that particular salt, no more will be abstracted from the soil, as there will be no cause for compensation; hence the difference of the amount of different ash ingredients in a plant are largely dependent on its selective power. Thus silica is more abundant in grapes than in leguminous plants though both may have their roots in the same medium, and it appears possible that further examination will prove that different varieties of coffee assimilate or reject certain of the soil constituents which though used as food by many plants are not appreciated by a particular variety.

93. It is a common though erroneous idea that the area occupied by roots is proportional to that of the branches growing above them; such a supposition has no foundation on fact, as roots vary in size and quantity according to the quality of the soil. A poor soil encourages the growth of long roots which have to travel far to search out and absorb sufficient nutriment for the plant, but in a good soil a few short roots will be sufficient to meet all demands. Though in a dry surface soil though roots may search for food, they are often assisted by a deeply penetrating root that enters the sub-soil mainly to abstract the water the others fail to supply in sufficient quantity. But although the length and structure of roots is not proportional to the parts of a plant above the surface of the ground, these are largely influenced by the roots. Thus roots growing in favorable conditions and exposing a large surface, force the head to extended and rapid growth, because the amount of fluid received by a plant depends on the size and extent of the roots and this food forced into the plant must be expended by it in the formation of branches. If roots be diminished by root-pruning when the plant is as nearly as possible at rest, the result will be to check undue luxuriance and induce fruitfulness the following season; but if roots be cut and injured by digging implements when the tissues of the plant are fully distended with nutrient fluid, not only will the plant be impoverished by the loss of the share of stored up matter taken away bodily

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by the removal of the roots ; but it will bleed copiously from the cut surfaces of the roots, and this will be encouraged by their contact with the soil which will encourage a flow of sap from the wounds by capillary attraction. In draining or trenching or in any operation by which the roots are bruised or otherwise injured, it is well to cut off the injured part with a sharp knife ; as, if left on the bush, they may rot and this morbid state may spread along the roots to the injury of the entire plant. To what an extent root-pruning can be recommended must depend largely on the condition of each estate. On poor soils it will generally be unnecessary ; but on a rich soil and on coffee grown under shade it may, after a succession of light crops when the plant develops gormandizers, be advantageous. Root-pruning is attended with considerable risk by those who do not understand its influence under varying conditions of season and plant growth, so that its value will be best tested by experiment on each estate. At the same time fear on the ground that injury may be done by the partial root-pruning, that is an inevitable accompaniment of deep cultivation must not be considered as a sufficient reason for stopping this operation, as the injury to the roots will be more than compensated for by the mechanical and chemical improvement of the land in which they are ramifying.

94. Although on germination roots issue independently of the nature of the soil, they speedily commence an apparent search for food. Those grow most rapidly and develop the greatest number of feeding rootlets that are in contact with an abundant food supply, while those that find no nourishment simply perish. The force of absorption by roots varies with the time of year and is proportional to the quantity of food that is required by the plant, hence, when the sap is being rapidly elaborated by young growing leaves and twigs, the roots are also in rapid action, but as the season advances and less growth is made, so the action of the roots diminish. At the same time roots of plants and especially evergreens are never wholly inactive, but during the cold weather continue to absorb food from the earth and convey it to the interior of plants ready for the demand by the young shoots of the succeeding season. In this way all the tissues of the plant become gradually distended, and the longer the period between the cessation of active growth and its recommencement the following season, the greater will be the amount of food stored up. Hence the desirability of "wintering" a plant as much as possible. It appears to me probable that a reason why leaf disease is less severe generally in India than in Ceylon is, that on our estates a pronounced season of almost total cessation of growth occurs through the dryness of the atmosphere and the absence of rain for many months, aided by a considerable difference between the temperature of the earth and air, while in Ceylon's more humid clime, the plant never enjoying so renovating a rest, is continually weakened by unnecessary growth. The water containing dissolved inorganic matters imbibed by the roots ascends chiefly by means of pressure from below, and the capillary attraction of the tubular organs of the plant, and in the day time by evaporation from the leaves in which it has to undergo a considerable change before it becomes elaborated into a directly nourishing fluid. The leaf of a plant may be looked upon as both stomach and lungs traversed by a series of arteries and veins, consequently the health of the plant will depend on the degree with which respiration, exhalation and digestion are perfected in the leaves. Anything tending to impede free action, whether it be fungus growth or its supposed antidote flowers of sulphur, merely dirt stopping the stomata, an atmosphere continually surcharged with moisture or containing poisonous gases, or an excess of shade to prevent the free admission of light ; may be looked upon as a cause to diminish the healthiness of the plant. It is only under the influence of sunlight that leaves are able to exhale large amounts of water. Thus a sun-flower plant has been proved to lose from its leaves thirty ounces of water during twelve hours of a warm day in Europe, but three ounces during a night without dew, and none at all during a night when dew was present. Light by stimulating the exhalation of moisture, thus increases the amount drawn up from the soil and consequently causes a larger quantity of food dissolved in the water to enter the plant. Under the action of light, leaves also exhale oxygen by the decomposition of the carbonic acid they have inhaled from the air, and perhaps sucked in to a small extent through the roots ; while the carbon of the carbonic acid is retained to build up vegetable tissues. The quantity of carbonic acid decomposed is in proportion to the intensity of the sunlight, and is consequently smaller in amount in shady places ; though plants naturally inhabiting shady spots would, from their epidermis not being of a nature to allow a free escape of water, be liable to be injured by a too free exposure to sunlight. I trust I am not venturing too far into chemistry for the majority of my readers when I quote an equation which shews at a glance the important actions I am discussing. We know the plant gets water through the roots and carbonic acid through the leaves ; that cellular tissue is found in the plant and oxygen exhaled by the leaves. Put into chemical language these changes are simply represented thus :—

$$6\,C\,O_2 + 5\,H_2\,O = C_6\,H_{10}\,O_5 + 12\,O$$

carbonic acid	water	starch Woody fibre or cellulose	oxygen.

95. Under some conditions the formation of vegetable tissue and the exhalation of oxygen ceases. At night it has been found that plants inhale oxygen and exhale carbonic acid, and as I have shewn with the sunflower the exhalation of watery vapour also stops or becomes insignificant according ot the condition of the atmosphere. There is another point too, to which the attention of coffee planters has not hitherto been directed, and that is the influence on plants of the difference between the temperature of earth and air in which they are growing. I here extract a portion of a table in Lindley's "Theory and Practice of Horticulture" to bring this point to notice in order that planters may make observations of their own to elucidate fully what can now be but vaguely indicated :—

Meteorological Observations at Trevandrum, Southern India, 203 feet above the sea.

Months.	Mean Temperature of earth, 3 feet deep.	Mean Temperature of air.	Difference, (the earth being the warmer).
January	84·94	78·93	6·02
February	86·83	80·38	6·45
March	88·79	82·73	6·05
April	80·61	83·37	6·24
May	88·41	81·60	6·81
June	85·00	79·02	5·98
July	83·25	78·45	4·80
August	83·56	78·99	4·57
September	84·57	79·97	4·60
October	84·72	79·07	5·64
November	84·62	79·75	4·87
December	84·22	78·03	6·19
		Mean.	5·69

I have to quote Trevandrum as I am unable to give any observations from coffee districts, though at greater elevations the differences would be more marked. Looking at the difference between the temperature of the earth and air it will be seen the earth is hottest in the dry months and its temperature falls rapidly when the rains commence, through the presence of a large amount of water in the soil, and by the obstruction of the solar rays by clouds. It will also be noted that the difference between the two temperatures is least in the rainy season and immediately after it.

96. As a plant at night practically ceases to exhale watery vapour, while its roots, uninfluenced either by light or the change of the air temperature continue to imbibe fluid ; it follows that the plant becomes surcharged and its tissues in a state of tension by the presence of a large amount of watery vapour. In the same way plants growing in shade, especially if in a very wet soil, become soft and flabby. This will become the more pronounced the greater the difference between the temperature of the soil and air, the less the sun-light, and the greater the amount of humidity in earth and air. If the roots are in a considerably warmer temperature than the branches and are thus in a medium favorable to quick absorption, while for any reason such as shade, prolonged absence of sunshine, extreme humidity of the atmosphere, or a lower temperature of the air ; the leaves have no reciprocal action, the presence

of superfluous sap will cause a plethoric condition of the plant unfavorable to health. These conditions in Mysore occur before those I have to note next as equally unhealthy. These are ; the branches being in a relatively warmer medium, with a clear sky and a maximum of sunlight, while the roots are in a cold clammy soil supersaturated with water, so that the leaves are consuming sap faster than the moisture can be absorbed by the roots. In mild cases this causes the leaves merely to droop as may be seen on any hot day ; but if severe, the leaves drop, and the berries either fall off or refuse to fill, their requirements not being supplied with sufficient rapidity, if other unfavorable conditions, such as insufficient manure, or a poor soil unworked, coexist with these unfavorable atmospheric conditions, the injury will be the more marked. Although atmospheric conditions cannot be altered, except in the matter of shade, it is quite possible to change the temperature of the earth by drainage, which, by the rapid withdrawal of what is or would become stagnant water, will raise the thermometer several degrees. At the beginning of the rains the soil is not saturated, so that the drains will not then increase a temperature already high, and a corresponding root action which would be injurious ; but later on when the sun reasserts his sway first fitfully between the showers, and later on in a cloudless sky, and the surcharged leaves gladly dissipate their watery vapour into the atmosphere; then the action of drains in rapidly withdrawing the excess of moisture from the soil, and so raising its temperature, becomes valuable. Under the first condition of a plant surcharged with sap and breathing with difficulty, the "rot" whether it be a separate disease or, as now seems probable a form of "*Hemileia*," meets with the most favorable conditions for development; while later on in the season a cessation of an excessive amount of water in soil, air and plant, an increasing amount of sun-light, and a falling temperature, all favor the creation of an impeded and sluggish circulation of the thickening sap, and the excretion from it of such matters as it parts with most readily.

97. We are now in a position to understand the action of pruning which must be conducted differently according to the object in view; whether for the production of wood, or to encourage flowers and fruit.* Woody matter cannot form of itself, but arises from the action of other organs. The elaboration of the sap is a process taking place in active leaves from which, when it has acquired the needful properties, it is distributed by ducts or arteries all over the plant, building up the requisite structures in each part. If we deprive a plant of its leaves we rob it of the means of elaborating nourishing sap, and the greater the reduction in leaf surface the greater will be emaciation of the plant. Before entering into a dissertation on the science of pruning, I must draw attention to "handling" which is a preventive measure to keep the tree from misdirecting its energy ; and in no species of cultivation can the old proverb "prevention is better than cure" be better remembered than in that of coffee. If a shoot that will ultimately have to be removed be left long on the tree, it absorbs more and more nutriment the longer it is left, and the larger it grows : and the wound caused by its removal becomes proportionately larger and more difficult to heal, while if woody tissue be formed its rupture when the shoot is removed, causes a jagged wound exposing a considerable surface through which the plant will lose a further supply of sap by its exudation and dissipation into the atmosphere. By permitting a shoot that is not required to remain on the tree, not only is there the direct loss of the amount of material it has formed for no useful purpose, but there is the indirect; for had the shoot not been there the sap would have flowed on to increase the luxuriance of other growth, the leaves would have been larger or more numerous, and consequently the whole of the plant would have benefited. Again handling is an operation that can be performed by the majority of the coolies on an estate of both sexes and all ages, whereas pruning requiring more care, is only to be entrusted to a few careful hands. Handling cannot be too frequently performed, and I may add if the tree look vigorous the absence of numerous gormandizers and flushes that require removal is a sign that the leaf surface and root surface bear a proper proportion to each other, while a reckless pruning will be followed by a large increase in handling operations.

98. In "topping" the effect of stopping the upward growth of the tree is to throw the elaborated sap descending from the leaves into the lateral branches. If a heavy crop be desired on these, a system not to be recommended on any young trees, and only to be tolerated on those of extremely vigorous growth ; the operation should be performed at a season when the tree is in most rapid growth, and the extreme and succulent tip of the central stem should be nipped off by hand. But desirable as a heavy first crop may be in the eyes of a planter who has expended his capital in "planting up" to the utmost, it will not pay in the long run, and it is the surer plan to defer topping until the shoot is more mature and the season of exuberent growth passed.

99. If a strong branch be required, it can be best produced by nipping off the ends of most or all of its competitors, but not lessening their leaf surface by which we must constantly remember sap alone can be elaborated. By nipping off the extreme end of a branch and leaving the leaves to perform their functions,

*On this subject for minute practical remarks see Hull's "Coffee Planter," also G. Anderson's "Jottings on Coffee."

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a large amount of sap full of nutrient matter is created, and its direction being arrested in some points it will act with greater vigour where there has been no check. In consequence the uninjured branch will lengthen with increased rapidity, from receiving a larger share of nourishment than it would have received, had the other growing ends not been checked, or had they been cut back too far so as to reduce the leaf surface. This is the use not the abuse of pruning. Now to take the other case of removing not only the tip but the greater part of the branches, and thus lessening to a serious extent the leaf surface. There being no stomach-like leaves wherewith to digest the matters ascending from the roots, the uninjured stem can only receive so much nourishment as its own restricted leaf surface can give; consequently, instead of increasing rapidly, it only grows slowly, while the plant strives to find an exit for the liquid forced up from the roots in forming gormandizing shoots too luxuriant to subsequently produce flowers and fruit. Here is the cause and effect of injudicious heavy pruning. It may be stated as an axiom in horticulture that whatever is favorable to excessive vigor in a plant favors the formation of leaves and succulent growth, and is unfavorable to the production of flower buds and fruit; while circumstances tending to diminish luxuriance and rapid growth without affecting the health of the plant are more favorable to the production of flower than leaf buds. On this principle other operations of pruning become expedient. Of these the removal of dead wood and all branches interfering with the free ingress of light and air to the centre of the plant are important. The removal of branches, generally secondaries, and tertiaries growing, or likely to grow, within 6 inches of the stem, is imperative on shaded estates, and advisable in most cases throughout the districts on which I am reporting. In many cases too on old coffee, I believe the lowest primary or pair of primaries may be eliminated with advantage, as they are much in the way of coolies when digging, and obstruct the free circulation of air close to the ground. On one or two estates in Mysore I feel convinced low topping has been carried to an extreme that is ill advised, and the reason urged that the land is too poor to grow a large tree is inapplicable. A tree with its first primaries some distance above the surface of the ground and topped six inches or a foot higher to allow for this, while containing no greater surface, would gain by a better circulation around the trunk, which would then be less liable to accumulate moss and lichens, and could be more readily cleaned.

100. The cleaning of coffee trunks is an operation that has been too long neglected especially on shaded estates, and I fully endorse the opinions of two Mysore planters who have brought this matter forward. I believe gloves made of coir fibre to be used by the coolies when handling are the best agents to employ, but in the absence of this material a whisp of straw may suffice. All but tender shoots, still green in color and likely to snap or bleed under the operation, should be rubbed. Though advantageous at all times, it is especially to be recommended in the height of the monsoon just before the mycelium known as "rot" or "*Pellecularia Koleroga*" can be expected to ascend to the leaves. If the stems be sufficiently dry they might be dusted with lime, and a *small* amount of powdered quick lime put round the earth at their base, and renewed every few days; thus severing the connection between them and the surface of the ground at the critical period of the year. This should be first tried on a small scale as an experiment, when the quantity of lime to be used without injury to the tree can be ascertained. It may be proved that with *Hemileia* there is a circulatory species of growth, one stage on the leaves where it yields orange spores for future growth; another as a mycelium on the leaves and stem, and a third stage when the spores require moist ground or perhaps another plant on which to germinate. Such a theory is plausible when we consider the wonderful series of developments of some animal and vegetable parasites. Thus the tape worm of the dog depositing its ova on grass becomes a hydatid in the brain of the sheep which grazes on the infected grass. *In the same way the life of the "*Hemileia*" may continue only, if occasionally, perhaps once in several generations, it passes through a complete course. Aerial spores may for a time have sufficient vitality to germinate, but unless vitality be now and then renewed by a complete circulation of the plant through all its phases they may not survive, or they may survive, but produce spores that will not germinate. This I think possible as a somewhat similar development of one of the "*Uridineæ*," *Paccinia Graminis* is given in Sach's text book of Botany."

"On the leaves of the *Berberis Vulgaris* are found in the spring yellowish swollen spots, where dense masses of mycelial threads are interposed between the parenchyma cells. In these swollen spots are found two kinds of fructification the *spermogonia* and the *æcidia*. The æcidium spores produced upon the leaves of *Berberis* do not develop a mycelium unless their germination takes place upon the surface of a leaf or stem of grass (as wheat or rye.) The germinating filaments then penetrate through the spores of the stomata, and the mycelium produced in the parenchyma of the grass generates within 6 or 10 days a form of fruit called *Uredo*. These uredo spores are dispersed after the rupture of the epidermis, and germinate after some hours upon the surface of the grasses, but in these they form new mycelia, from which in 6 to 10 days, new uredo fruits again arise, while

* For many further illustrations on this point see "Animal Parasites and Messumates."

the germinating filaments of the spores penetrate into the interior through the stomata. While the fungus is multiplying in this manner for several generations on grasses, during the summer in its uredo form, the production of a new form of spores begins in the older uredo fruits ; long two celled spores, the *Teleutrospores*, being also formed near the roundish uredo spores. The formation of uredo-spores in the uredo-fruits then entirely ceases, and teleutrospores only are produced, and with them the period of vegetation closes. The teleutrospores persist on the grass haulms through the winter and do not germinate till the spring; they emit from their two cells short septate germinating filaments at the end of which, on slender branches, the *Sporidia* are produced. These sporidia develop a new mycelium only when they germinate on the surface of the leaves of the barberry ; but their mode of germination differs from that of the other form of spores, their germinating filaments penetrating, as in the Peronosporeae, into and through the epidermis-cells, and thus reaching the parenchyma. These there form a mycelium which produces the swelling of the leaf constituting the first stage which we considered, this mycelium again generating spermogonia and æcidium fruits. If within the cycle of this alteration of generations, a fertilization or conjugation occurs, it must probably be looked for on the mycelium in the barberry leaf, so that the *æcidium*-fruit would be the result of it."

The Rev. R. Abbay, whose microscopic examination of this pest is invaluable, had not up to December 1878 been able to infest growing coffee plants, though the temperature, 90° F. employed during his experiments may have been too high, or the plants on which he has experimented may have been too healthy. I quote his remarks on this subject as some one who reads them together with the suggestions I have thrown out may be able to add a link to the life history of the pest and so serve both science and the interests of the planting community. "Conditions of *growth, &c.,"

"With regard to the conditions of growth of *Hemilia Vastatrix* many attempts have been made to infest growing coffee plants both through their young and fully formed leaves. The same has been tried with coffee leaves placed in an atmosphere saturated with moisture and kept at a constant temperature of 90° F. (I would suggest 60° to 70° F., F. E. H); " but in no case has the attempt succeeded, although the sporanges, the growing mycelium, and the conidia have been placed on the leaves. What the necessary conditions are which are absent, it is different to imagine, unless it be that the stomates through which alone apparently the fungus finds its way into the leaf, are too contracted under the artificial conditions supplied to allow the mycelium filaments, or the spores to enter. The conidioid form of the fungus may readily be grown on the outside of the coffee leaf in a moist atmosphere ; but it does not appear to penetrate into the leaf; for in the case of such filaments I have never seen either the mycelium within the tissues of the leaf or the cluster of red sporanges outside it. The latter form, the common one by which the "disease" is recognisd in Ceylon. I believe to be the dry weather form of the fruit, appearing generally in its greatest intensity soon after the rains have ceased, but very rarely during their prevalence. During the prolonged wet season the conidia have been found growing on many other plants as well as on the coffee tree ; but the mycelium remains on the outside and the leaves shew no traces of the disease. If it is necessary before the fungus can affect the leaf that the stomates should be in a specially favorable condition for receiving the infection (a condition perhaps only occurring in certain stages of the plant,) this might be the reason why in the midst of such countless multitudes of spores every coffee leaf is not covered with "disease" spots. On the other hand it may be due to the fact that for some obscure reason only a very small proportion of the spores will germinate. It is also possible that my inability to grow the red sporanges is due to the fungus requiring some other tree or plant on which to develop before it is able to infect the coffee tree ; but this is improbable."

These extracts give but a faint idea of the difficulty of working out *in extenso* the life history of this fungus. Allied forms as we see carry on their life by means of so many kinds of fertilization, that we may well regard a single method of cure as hopeless. Thus we have zoospores which, quickly germinating in water, are capable of floating about with an animal like mode of progression. In the common garden cress these spores neither infecting the roots nor the leaves inoculate through the medium of the colyledons or seed leaves by thrushing out a germinating tube through which the contents of the zoospore enter the stomata of the leaves. That these zoospores exist as a stage of the existence in the life of the *Hemileia* is probable, for the Revd. R. Abbay says :—

"With regard to zoospores I have several times found them on the slips under circumstances that suggested a connection with the cellular mycelium or conidia of *Hemileia*, but I have never been able to determine whence they came."

Again another kind of reproductive organs produced either terminally or laterally upon the threads of the mycelium are known by the names of "Oozonia" and "antheridia." The latter containing granular protoplasm penetrates the former, fertilizes it, and changes it into an "Oospore" which is endowed with lengthened vitality and capable of germinating when placed on a humid soil or other favorable condition for springing into life. This form also probably assists the *Hemileia* in its struggle for existence as the Revd. R. Abbay remarks :—

* Journal of Linnean Society Vol. VII, No. 100, December 1879.

"In one or two instances they (*i. e.* the cells of the mycelium swelling into a sac-like form) have presented an appearance suggestive of conjugation; but at this point the growth of the fungus ceased, and I was not able to detect any actual communication between what appeared to be the "antheridium" and the "oogonium." Under more favorable circumstances it is possible such a conjugation would have taken place."

Besides the Zoospores and Oospores whose action is at present uncertain, there remains as known germinating organs, the spores primarily contained in the sporange, and the conidioid form of fruit from both of which mycelium is produced.

101. Bearing in mind the numerous ways in which the existence of the life of fungi is prolonged and remembering, notwithstanding recent researches, how much there still remains to be positively ascertained of the different phayses of the *Hemileia* before we know every link in its life history; I think it should be acknowledged how small a chance there appears of discovering a single simple remedy that will rid estates once for all of the pest. If we could arrest at any point the development of spores essential to the circle of life which it seems probable the *Hemileia* leads, we might hope to combat the disease directly, and it seems the most likely period at which such an attack would be effectual would be not when the mycelium is entering the stomata of the leaves or when the yellow sporanges are leaving the leaf, but when the fungus is in some form or other on the ground, or on another plant that might be totally destroyed without loss to the planter. With the present imperfect state of our knowledge, I cannot indicate the exact time and mode of such an attack, consequently I am driven to suggest the use of lime in the way I have indicated as a possible, partial, palliative; and to recommend strongly the various agricultural and horticultural operations I have discussed as means through which, by increasing and directing the healthy vitality of the tree, it may be placed in a better condition to withstand the attacks of our scourge "*Hemileia Vastatrix*." At the same time though I consider good cultivation the best means to reduce the chances of a plant being attacked, or, if attacked, seriously injured, I do not anticipate it will wholly overrule meteorological conditions favorable to the development of the parasite to such an extent as to eliminate it entirely; hence a continued rather than an intermittent system of thorough cultivation must be adopted.

102. In conclusion, I may add I have avoided throughout the report the names both of planters and estates at the request of several correspondents, but I cannot conclude without thanking all the planters with whom I came in contact for their hospitality, especially A. Alston, Esq., Honorary Secretary, Coorg Planters' Association; R. Stephenson, Esq., Honorary Secretary, Mysore Planters' Association; and G. Anderson, Esq., and also these two latter gentlemen for their valuable notes and cordial assistance in the compilation of this report.

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